VITALISM AND SCHOLASTICISM

BERTRAM C. A. WINDLE


Ex-libris
Charles Atwood
Kofoid
BMC

VITALISM AND SCHOLASTICISM

VITALISM AND SCHOLASTICISM

BY

BERTRAM C. A. WINDLE

M.A., M.D., SC.D., LL.D., F.R.S., F.S.A., K.S.G.
OF ST MICHAEL'S COLLEGE, TORONTO

Pulchra quæ videntur, pulchriora quæ existimantur,
longe pulcherrima quæ ignorantur.

LONDON
SANDS & CO.
15 KING STREET, COVENT GARDEN
AND AT EDINBURGH

PRINTED IN GREAT BRITAIN BY
THE DUNEDIN PRESS LIMITED, EDINBURGH

TO

MY GUIDE, PHILOSOPHER AND FRIEND

THE RIGHT REV.

MGR. HENRY PARKINSON, D.D., PH.D.

RECTOR OF ST MARY'S COLLEGE, OSCOTT

IN MEMORY OF

MANY SYMPOSIA IN SUTTON PARK AND ELSEWHERE

SIC REDDIT AD DOMINUM QUOD FUIT ANTE SUUM

CONTENTS

CONTENTS

PREFACE

A LARGE portion of this book appeared some ten years ago under the title of *What is Life*, and met with a very favourable reception, but has begun to exhibit tendencies of being out of date, owing to the large number of books and papers on the subject with which it dealt which have been published since it saw the light.

The present issue includes the greater part of the former work with new matter in response to the need mentioned above, but with something more. In some of the very valuable books which have been published on the side of Vitalism during the past ten years, there have been given accounts of the history of the conflict between vitalists and anti-vitalists throughout the centuries, but without exception these ignore or almost ignore the position towards the subject assumed by the Philosophers of the School. I cannot understand still less excuse this neglect, and it has been a part of my object to deal with an aspect of the controversy which has been thus, as I think, unjustly neglected. The former work

was kindly read for me by my very dear and deeply regretted friend, the late Fr. Michael Maher, S.J., whose kindness in this and other ways I can never forget.

My friends, the Right Rev. Mgr. Parkinson and Professor Hartog, D.Sc., have read parts of the present volume, and thus laid me under deep obligations. Need I say that whilst the former bears no responsibility for my science, the latter is equally innocent in respect of my philosophy.

Bertram C. A. Windle.

VITALISM AND SCHOLASTICISM

CHAPTER I

CHANGES IN SCIENTIFIC OPINION

Alchemists and Chemists—Vitalists, Mechanists and Neo-vitalists

Scientific opinion regarding any particular point is apt to waver from view to view as new facts swim into one's ken; it swings from one side to another like a pendulum and is sometimes found, after a long interval of time, to have returned to a position which it might have been supposed had been abandoned for ever. That such must necessarily be the case will not require much demonstration when one remembers the vast number of undiscovered facts which lie all around us and the potent and corroding effect which the discoveries of to-morrow may consequently have upon the most cherished theories of to-day.

Alchemy

In the pre-scientific period, as some would call it, at any rate a period when science was

in an even more crude and chaotic condition than it is to-day, the chemists, or, as they were then called, the alchemists, believed that there was a *materia prima*, a simple essence out of which all existing substances were built. And this being the case they held that there was no real reason why any one substance might not be turned into any other, no reason, for example, why lead should not be transmuted into gold. Stripped of all its gorgeous imagery, deprived of its Red Dragon and the other fanciful terms which it brought into its nomenclature, this was the underlying theory which dominated all the work of the alchemists. This domination continued until 1661, when Robert Boyle—"The Father of Chemistry and the uncle of the Earl of Cork," as his monumental inscription styles him—published his "Skyptical Chymist," and turned men's minds to the conception of unalterable and *ab initio* distinct elements. And as time went on and new discoveries were made, men laughed at the follies of the alchemists and wondered that any persons could have been so foolish as to imagine that there was really only one kind of basal principle of which the things that are were various and differing manifestations.

Chemical elements

So we were taught that there were seventy to eighty chemical elements, and that each of

these was a simple and undecomposable substance incapable of being split up or of being transmuted into anything else but itself. And so the underlying theory became and for long remained one which proclaimed an essential and absolute difference between the so-called chemical elements.

Time rolled on, and but a few years ago M. and Mme. Curie discovered radium, and the extraordinary facts of radio-activity began to be gradually brought to light. Following upon these discoveries has arisen a new theory of matter wholly different from that which has for so many years held the field. This theory teaches that within the atoms of which all chemical elements are made up are electrons or corpuscles, and that these corpuscles may be moving units of negative electricity, ensphered by an envelope of positive electricity.* Moreover, it teaches that the differences between the atoms of any two substances is a difference of arrangement in the ether with which they are associated. Now a single glance will show that this is really very close to the theory of the alchemists, as will be more fully shown in a succeeding chapter. If all things in their ultimate analysis are constructed from

Radium

* There are other views, for which manuals on Physics and on the Composition of Matter must be consulted.

a common and indifferent *materia prima*, it is clear that there is no inherent impossibility in the proposition which asserts that means may yet be found whereby the fundamental arrangements of one molecule—say of copper—may be so altered that it becomes transmuted into another totally different molecule—say of gold.

It is, of course, true that the views thus briefly outlined are not yet in any way fully established, and that at any moment further facts may come into notice which may utterly upset both this and the earlier hypothesis. But the example will suffice to show how uncertain even the oldest and most respectable scientific theories may really be, and will also serve as an excellent parallel to the changes of opinion which have taken place in connection with the question with which this present book is concerned, that is the nature of life and of living things.

Scholastics and Vitalism

Those biologists—if we may so speak of them—who flourished at the same time that the alchemists were endeavouring to discover the philosopher's stone, had no doubt at all as to the existence of some further factor in living things than those which were to be met with in inorganic objects. Fr. Maher * tells us that

* *Psychology*, 5th ed., p. 469

"the principle of life in the lower animals was held by the schoolmen to be an example of a simple principle which is nevertheless not spiritual, since it is altogether dependent upon the organism, or, as they said, *completely immersed* in the body. St Thomas accordingly speaks of the *corporeal souls* of brutes." In fact the scholastic philosophy assigned what is called "souls," sensitive and vegetative souls, to vegetables as well as to the lower animals, and by that term "soul" signified that principle of life which, as vitalists hold, is the factor—the elusive but none the less certainly existent factor—which distinguishes living from non-living matter, which places the simplest of organisms, say the microscopic Amoeba, in a position separated by a gulf of immeasurable width from the most complicated product or substance of the inorganic world. Such in essence was the view at the period in question, and it is a theory which, unlike that of the alchemists, has never ceased to have its adherents.

In a succeeding chapter the views of scholastic philosophy on this question will be briefly detailed: meantime it is perhaps hardly necessary to say that writers of this school were unanimously vitalistic. This continued to be true to what some would call the end of

the scholastic period, for Petrus Pomponatus (1464-1524) otherwise Pomponazzi, whom some have called the last of the schoolmen,* whilst he held that Aristotle believed the human soul to be mortal and seems to have upheld that opinion himself, was fully vitalistic in his views.

Philosophers and Biologists

During this period the discussion was carried on, as indeed it continued to be later, by those who would be more fitly described as philosophers than as biologists: perhaps, however, it is fairer to say by the learned men of the time, for much of the time it was possible for intellectual giants like Aquinas to be masters of all the learning of the day. Nowadays the difficulty is to know all that can be known about any one specialty and the result is that few scientific men can fairly be described as philosophically learned nor have philosophers —with very rare exceptions such as Driesch— endured a practical scientific discipline. After the period of which I have been writing, Vitalism passed into what Driesch calls its second

* Even if one subscribes to the opinion that the schoolmen came to an end about this period—a highly disputable thesis—it is hard to see why Cardinal Cajetan, a much more important writer than Pomponazzi from the scholastic point of view, should be denied the title claimed for the other writer. Thomas de Vio, otherwise Cajetan, was born in 1468 and died in 1534, so that he covers practically the same period as Pomponazzi.

period, during which biology gradually grew up and became a separate, well-defined branch of science, a result which was, he thinks, mainly due to the writings of Caspar Friedrich Wolff (1733-1794) and J. F. Blumenbach (1752-1840), and especially of the last named, with whom, as he says, "the old Vitalism reaches its height." *

End of the old vitalism

What caused the change of opinion with regard to the vitalistic theory which actually took place, for it is, so to speak, only yesterday that hardly a voice was raised anywhere in its favour? According to Driesch, "the old Vitalism died literally by a process of self-extermination, for just as political parties are said to perish if they experience no opposition, so may scientific and philosophical theories. From the fact that they are never subject to attack and never expect to be, they cease to be guarded, and new pieces of knowledge which might seem fatal to them, yet might actually be fitted legitimately into their framework, are allowed to rise unheeded until the moment of revolt arises and the worn-out defences, antiquated

* Only so much of the history of the subject as is necessary to make the rest of this book intelligible will be given here. For fuller details readers may be referred to Driesch, *The History and Theory of Vitalism*: London, Macmillan, 1914 (*Ref.* Driesch. Hist.) which deals with the history—omitting the scholastics—with great completeness; and M'Dougal, *Body and Mind*: London, Methuen, 1911).

and decayed, are for a time unable to withstand the assault." Such, he thinks, was the case with the older Vitalism, and such indeed, according to the learned de Wulf, seems to have been more or less the history of the later scholasticism * in its day of decadence. Neither Scholasticism nor Vitalism was dead, however much they may have had that appearance. Both have come to the front in full vigour, and have done so by firmly facing every new discovery of science and welding it, where possible, into their system. Moreover, as will more fully appear in later pages, these new facts of science —even the most startling of them—have been singularly favourable to the progress of both the schools of thought to which we have alluded.

The second half of the nineteenth century was emphatically a period of revolt, and amongst the doctrines attacked none received a severer handling than that of Vitalism. Two of these attacks, both belonging to the middle part of the century, were really good, and, according to Driesch, were "first-rate." The first of these was Lotze's article in Wagner's *Dictionary of Physiology* (1842), which he calls "the most solid of all attacks upon Vitalism."

Lotze and Bernard

* See the account in his *Scholastic Philosophy*, trans. Coffey: Dublin, Gill, 1907.

Yet in his later works Lotze seems to have taken up an opposite opinion or to have considerably modified his view, since he is described by McDougall as the "most brilliant and thoroughgoing modern defender" of Animism. Claude Bernard, also, though a vigorous critic of many of the details of the older ideas as to Vitalism, adhered to its main thesis.

It was not, however, direct writings in criticism of the theory which led to the temporary capture of the ancient fortress. Two other theories swept over it and seemed for a time to have completely destroyed it: with both of which we shall have to deal in subsequent chapters. By far the most important of these was, and is, that of the Conservation of Energy, foreshadowed by Watt but first formulated by Robert Mayer (1814-1878), who has the credit of being its author, and by Joule.

Only second to it was the rise of Darwinism. The opinion as to the magnitude of the content of these two doctrines which held the field during the latter part of the nineteenth century is not quite that held to-day, certainly in connection with Darwinism and, in the minds of not a few, with regard to the much more important theory of the Conservation of Energy.

However, these are matters which must

receive fuller treatment, each in its proper place. In the next chapter it will be seen what radical changes of opinion have taken place during the last three-quarters of a century.

CHAPTER II

THE DECADENCE AND REVIVAL OF VITALISM

Huxley—Burdon—Sanderson—Le Dantec—Haldane—Moore

There is, in any case, no doubt that with the great outburst of scientific investigation and scientific knowledge which took place in the nineteenth century the vitalistic theory came to have its strenuous opponents. There were those who maintained that it was a mere piece of mysticism, and even at the present day, as we shall shortly see, there are many who would as soon confess their belief in the existence of a vital factor in living things as they would admit the existence of an Almighty Creator of all things. Both these ancient views would to them seem to savour of superstition and to belong to a dark age of science. Perhaps in the beginning of the scientific outburst such a point of view was comprehensible if not legitimate. There were—as there still are—an extraordinary number of scientific facts lying around waiting to be picked up. The very number, variety and importance of these

was intoxicating and it is not hard to understand how men came to think, for a time, that there was nothing in the earth or in the heavens over the earth which was past their finding out. And so Professor Huxley * proclaimed that "the whole world, living and not-living, is the result of the mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulosity of the universe was composed."

Anti-vitalists

And again † he stated "that the living body is a mechanism . . . is now the expressed or implied fundamental proposition of the whole of scientific physiology." There is a curious difference between the phrasing of the first and second editions of this article which very clearly shows how definite the late professor's views were on this point, and how rigidly he excluded any such thing as a vital force from his philosophy. In the first edition he wrote: "Our volition counts for something as a condition of the course of events." But in a later edition, fearing evidently lest he might have seemed to have bowed down in the House of Rimmon, he altered this so that it reads: "Or, to speak more accurately, the physical state of which our volition is the expression." And

* Belfast Address, 1874. † *Collected Essays*, i., 163.

here he shows himself to have been a whole-hearted adherent of the most rigidly mechanical school. The first quotation is consistent with a vitalistic view of life, for no one will deny that in certain respects the human and other bodies are mechanisms and that the processes which take place in them are to be explained in terms of chemistry and physics. But the vitalist would add to this the statement that all the processes which take place in the body are not explicable in these terms, and, moreover, that none of them find their full explanation in any such way. Huxley's second statement shows that his view was not such as has just been indicated, but agreed with that put forward, in 1889, by the late distinguished physiologist, Professor Burdon Sanderson,* that "for the future, the word 'vital,' as distinctive of physiological processes, might be abandoned altogether," a statement, the inaccuracy of which will very shortly be made manifest. A similarly rigid view is held to-day by a number of scientific men, and as an example of one of a recent utterance of this kind

Burdon Sanderson

* At a later date he had modified his opinion, for Professor Hartog, in his *Problems of Life and Reproduction*, says that in 1900, when talking to him and Prof. Ch. Richet, Burdon Sanderson said: "The real meaning of life is adaptations," "using the word," Hartog continues, "evidently in the same sense as 'self-regulation'!"

Le Dantec may be cited the statements of M. Le Dantec* that "between life and death the difference is of the same order as that which exists between a phenol and a sulphate, or between an electrified body and a neutral body. In other words, all phenomena which we can study objectively in living beings can be analysed by the methods of physics and chemistry" (p. 5). And again (p. 250), speaking of the possibility of the artificial fabrication of a living cell, he says: "When the effective synthesis is obtained, it will have no surprises in it—and it will be utterly useless. With the new knowledge acquired by science, the enlightened mind no longer needs to see the fabrication of protoplasm in order to be convinced of the absence of all essential difference and all absolute discontinuity between living and not-living matter."

We can now see clearly the meaning of this explanation of life. It teaches that all the phenomena exhibited by living bodies, including the poetry of Shakespeare and Wordsworth, the profound reasonings of Aristotle or Sir Isaac Newton, the generous instincts of a Fry or a Howard, these and all minor manifestations of life are explicable and may, therefore, some day

* *The Nature and Origin of Life*, Hodder & Stoughton, 1907.

be explained in terms of chemical equations and physical experiments. It seems a hard saying, and one thing is clear, namely, that if it is true, there is an end to biology as a science, an end also to psychology, an end to all branches of science dealing with living things, since all these must resolve themselves into branches of the two only sciences of chemistry and physics.

Neo-vitalistic

But there are others who refuse to accept this explanation of life, and to set forward the arguments in favour of their point of view is the object of this book. And first it may be pointed out that some of those processes in the human body, which forty or fifty years ago seemed most clearly to be mechanical in their nature, some of those processes to which Burdon Sanderson alluded in the quotation above, some of these processes have, in later years, been shown to be wholly inexplicable in terms of a mechanical explanation. One or two examples of what is meant may be included in this general preliminary sketch of the subject—though they will be more aptly and fully considered in a later section.

The food which we take into our stomach is there and elsewhere in the alimentary canal acted upon by various juices and converted into a digested semi-fluid substance capable of

absorption and utilisation by the body. This substance passes through the cells which line a portion of the alimentary tract, and it was formerly supposed that this passage through the cells was of the nature of a filtration, or at least of an osmotic process such as may take place through a dead animal membrane.

But more recent experiments have shown that the occurrences which take place cannot be explained in any such mechanical way, but that there is another factor or there are other factors at work which do not come into operation in connection with the process of chemical

Secretion

osmosis. Again, the process of secretion by glands, such as those which produce the saliva, is now known not to be one in which the secreting cells "act in a passive inert manner as filtering mechanisms, or as membranes possessing constant permeabilities for different dissolved substances in the plasma, or as media in which different substances possess different solubilities." This "is proven by many experimental observations. Thus that the rate of secretion is not merely passively dependent upon blood pressure and blood supply (although under normal conditions it is subject to variations corresponding to changes in these physical factors) is shown by the observation of Ludwig that the secretion pressure in the

submaxillary salivary gland, when the outflow is resisted by fluid in a manometer, may rise much above the arterial pressure; and also by the observation that after administration of a drug, such as atropin, the blood supply may be increased as much as before administration of the drug on stimulation of the secretory nerve, without, however, calling forth any flow of secretion."* These and other instances, such as that of oxidisation, which might also be cited, show that further knowledge has disposed of the simpler mechanical explanation, which at first seemed to be sufficient, in favour of another and far more complicated solution of the difficulty.

These and other difficulties, which it will be the business of this book to bring forward, have led many men of science to abandon the mechanical explanation of nature as inadequate, and have caused them to endeavour to substitute for it a further theory of living matter. Thus Dr Haldane † says: "In a **Haldane**
living organism there is a specific influence at work, which so controls all the movements of the body and of the material entering or leav-

* B. Moore in *Recent Advances in Physiology and Bio-Chemistry*, ed. L. Hill, Arnold, 1906.

† *Nineteenth Century*, 1898, ii., p. 400. In this article the writer may be looked upon as a "Herald of Revolt" in this particular question in England.

ing it, that the structure peculiar to the organism is developed and maintained." And again: "To any physiologist who candidly reviews the progress of the last fifty years it must be perfectly evident that, so far from having advanced towards a physico-chemical explanation of life, we are in appearance very much farther from one than we were fifty years ago." As an American witness, Professor Wilson, perhaps the most eminent exponent living of the problems of cell-life, may be cited, and he tells us * that "the study of the cell has on the whole seemed to widen rather than to narrow the enormous gap that separates even the lowest forms of life from the inorganic world."

Wilson

Well might Von Bunge, the celebrated German organic chemist, declare, as he did in 1886, at almost the very date when Huxley and others were ringing the knell of all but mechanical explanations, that "the mechanical theories of the present are urging us surely onwards to the vitalistic theory of the future."

It is somewhat curious that vitalistic views have made much more headway in America and in Germany than they have done in England, and this has been explained by the un-

* *The Cell in Development and Inheritance*, Macmillan & Co., 2nd ed., 1900, p. 434.

doubted fact that the biologists of the two former countries have devoted their attention much more largely to ontogenic questions, that is, to matters relating to the life-histories of living things, whilst English attention, thanks no doubt to the stimulus given by Darwin, has been more directed to pylogenetic inquiries, that is, to the consideration of relationships between different living things.

It is also a curious point that physicists and chemists are far more chary of agreeing to the chemico-physical explanation of life than are biologists, and this fact is no doubt explained by the greater knowledge of the limitations and possibilities of their subjects which is possessed by chemists and by physicists as compared with the acquaintance with those subjects which falls to the share of most workers in biology.

Liebig in his day (1803-73) declared that the opponents of Vitalism were mostly strangers to the sciences which investigate physical and chemical forces, and we shall yet encounter more than one instance where biologists have claimed from chemistry and physics positions which chemists and physicists have been unwilling to surrender to them.

When mentioning Liebig, one cannot refrain from thinking of another class to which he

refers, opponents of Vitalism who are mostly strangers to *all* the courts of science, of whom he speaks as "dilettanti who have strolled as far as the portals of scientific research, and then claim the right to discourse to an ignorant and credulous public how the world of life really arose and how far we have got in the solution of the deeper problems." Fifty years since this was written, and how true it is to-day!

Neo-vitalism terminology

To return, however, to the point with which we were dealing, it must be admitted that the upholders of a vitalistic view do not always describe themselves as vitalists. But neither do the supporters of the electron view of matter call themselves alchemists. It is the fashion now to be neo-something or another, and so, besides neo-Darwinians and neo-Lamarckians, we have "neo-vitalists," who describe the entity which it would be superstitious to call a "vital principle" under some other name. Williams calls is a "genetic energy"; Cope a "growth- or bathmic-force." Henslow speaks of it as a "property of self-adaptation," and Eimer as one of "direction." Professor B. Moore,* who is one of the most recent persons—we are dealing here only with competent persons and not with incompetent

* *Op. cit.*, p. 4.

expositors—to deal with this matter, calls it "biotic energy," and does so, as he says, to "avoid confusion with ancient fallacies."

His remarks are so important and so illuminating that they will bear fuller quotation. "It is unfortunate," he says, "that the rebound from the bondage of the old view of a mysterious *vital force* or *vital energy*, possessing no connection or correlation with the forms of energy exhibited by non-living transformers of energy, should have led to the equally mischievous view of the present day, that no form of energy whatever is present in living cells save such as are seen in the case of non-living matter." Then he suggests his own term of "biotic energy," to "represent that form of energy peculiar to living matter, and exhibited in those energy phenomena which are confined to living matter, and are indeed its intrinsic property, by which it is differentiated and known to be alive. It must be pointed out that this point of view is equally distinct from the ancient one of vital force, which postulated something entirely distinct from the forms of energy of the non-living world, and on the other from the modern view that there exists in living matter no form of energy which is not *identical* with the forms of energy exhibited in non-living structures."

"Biotic Energy."

In this passage Professor Moore appears to depart from his usual lucid clearness. Two things must be either identical or distinct, and the question as to whether they are distinct or "entirely distinct" is one of degree and of minor importance. Now, on the writer's own showing, his "biotic energy" is not identical with the forms of energy exhibited by non-living matter. It must therefore be distinct from such forms. When this point is taken into consideration there does not seem to be any real difference, save one of terminology, between Professor Moore and other neo-vitalists and the schoolmen who taught, in their own language, which few men of science think it worth their while to try to understand, that the vital principle (or, if you will, for we will not quarrel over terminology, the "biotic energy") is a simple principle which is entirely dependent upon the organism, or, as again they put it, is completely immersed in the body. That it should have been called a corporeal soul is again a matter of terminology. Let it be noted that this view is a wholly different one from that which looked upon the soul or vital principle as a kind of little super-man existent
Descartes in some part of the body, as Descartes supposed it existed in the pineal gland. So far as the present writer is capable of understand-

ing the views of Professor Moore and others who hold like opinions with him, there is no real difference, no difference at all but one of terminology between him and older writers—or at least many of the older writers on the vitalistic question.

At least this may be said—that all alike proclaim that in living bodies there is something else present in addition to what is found existing in non-living bodies, and that "something over" is—whatever we call it—the vital principle as defined by the schoolmen from whom quotation has been made.

There have been, as we shall see, various attempts made, as indeed the passage above quoted is an attempt, to find a *via media* between Vitalism and blank Materialism, but, it must be confessed, so far without any success. Nor indeed can success be hoped for since it is difficult to see what *tertium quid* can possibly exist between "living" and "non-living" matter.

This brief sketch will serve as an introduction to our subject, and having next surveyed the scholastic position in general we can commence a systematic examination of the question of Vitalism.

CHAPTER III

THE SCHOLASTIC POSITION

Scholastic Philosophy and Catholic Dogma—Matter and Form—Mineral, Vegetable and Animal Forms or " Souls "—The Human Soul.

As the object of this book is not merely the discussion of the problem of Vitalism, but the discussion of that problem in its philosophical aspect from the point of view of the scholastic system, it is of the first importance to set out what that position is, and this must now be attempted. This is the more necessary since the chief books which have appeared on the subject of Vitalism have ignored or misunderstood the scholastic position.*

Scholastic Philosophy and Theology

To commence with, it is necessary for readers to disabuse themselves of the idea, if they should possess it, that the teachings of Scholastic Philosophy are " doctrines " of the Catholic Church. The idea exists and even in quarters

* I allude here to two books of prime importance mentioned in the note on p. 19. I shall have to quote frequently from both these books, and note here their excellence and the significance of their almost complete indifference to the scholastic views.

where one would scarcely expect to find it, and is responsible for misconceptions which it will be well to clear up once for all before any further progress is made with the subject itself. For example, M'Dougall (p. 33), in his summary of the history tells us that the philosophy and psychology taught by St Thomas Aquinas, which, he adds, were "the culmination of the scholastic efforts," "have remained with comparatively little change the accepted doctrines of the Roman Church.".

Here there is a curious confusion in the use of the word "doctrines," often used in place of dogmata. If the author just quoted supposes—and this would appear to be the meaning of his words—that the teachings of Scholastic Philosophy are or become dogmata of the Catholic Church, then he is absolutely wide of the mark. The dogmata of the Church belong to the domain of Revealed Religion and rest, therefore, primarily on Authority. Scholastics have never ceased proclaiming that authority is the weakest basis for philosophical structures to be erected upon. "*Auctoritas cereum nasum habet, in diversum potest flecti sensum, rationibus roborandum est*," said Alan of Lille, and St Thomas Aquinas himself says: "*Locus ab auctoritate quæ fundata super ratione humana est infirmissimus*." Finally, to com- Authority

plete this statement by quoting the remarks of the present erudite Professor of Philosophy at Maynooth—whose orthodoxy is not suspect—in an article on "Philosophy and Sectarianism." * "Anyone who has even a superficial acquaintance with scholastic philosophy will be aware of its clear and emphatic insistence on the fact that no *authority*, human or divine, can be the *ultimate* 'test' or 'criterion' of truth, or the last underlying ground for our assent, and acceptance of, any truth; and for the very simple reason that whenever we do assent to truth on authority, we must first have employed our own *reason* to estimate and judge the *evidence* forthcoming on behalf of the knowledge and truthfulness of that authority."

No doubt it is due to want of clear knowledge of this very important distinction and confusion arising therefrom that MacDougal commits himself to the statements that (i) "the University of Paris adopted the ingenious subterfuge of distinguishing two forms of truth, the theological and the philosophical, in order to free scientific speculation from the restrictive influence of the Church" (p. 38; and (ii) "this additional and superfluous soul

* *Irish Theological Quarterly*, Oct. 1910.

was added by Telesio to his scheme either as a prudent concession to the Church or because his philosophical and his theological opinions were formed in separate 'water-tight' compartments of his mind, while he was too honest to accept the current convention which admitted two kinds of truth, the theological and the philosophical" (p. 43).*

I cannot say what Telesio did or did not mean, as I have never studied his works, but nothing can be more clear than the fact that scholastic philosophers were never tired of proclaiming the fact that there is and can be only one true view of every topic. The confusion arises from the fact that they would hold that there were different truths established by different methods:—truths philosophically proved and truths received on authority after that authority had been accepted as adequate. This is perfectly intelligible and rational, but to suppose that sane men could conceive of two opposite explanations of the same thing being both true, men too, in whose epistemology the principle of contradiction took so high a place, is quite impossible. Of course, it is right that

Two kinds of truths

* The error of the two standards of truth *was* held by Averroes, who has no sort of title to be considered a scholastic or even an orthodox philosopher, and by a few other equally unorthodox writers, especially of the Renaissance period.

the Scholastic Philosophy—Thomism, if you like—is in a sense the official philosophy of the Church, and more than ever so since the publication of Leo XIII.'s Encyclical, *Aeterni Patris*, and that many explanations of Catholic dogmata are closely wrapped up with its methods and nomenclature. Hence it is unlikely that it will ever cease to be the official philosophy, but it would be quite incorrect to suppose that it has not had and, in some eyes, still has rivals such as the Augustinian, which in some matters departs considerably from the Thomistic, and the Rosminian which, however, never met with such acceptance as the others just named, and was condemned in 1887 by the Holy Office. Further, there were the Scotists or Franciscans of the 14th and later centuries. For several centuries Cartesianism was quite common in the Church. The Suaresian interpretation of St Thomas, adopted commonly by the Jesuits, is another form of philosophy accepted within the Church.

Having made this distinction clear, we may now turn to consider what scholastic philosophy does teach about Vitalism, since that teaching has been so much ignored and misunderstood by certain writers. As the object of this book is in part to set forth the relations between modern ideas on the subject it deals

with and scholastic teachings, no attempt will be made to prove these teachings which will be briefly stated below.*

Matter and form

The Thomistic philosophy, founded on that of Aristotle, regards all bodies as units, but units in which we must recognise two aspects, the substrate or "Matter," and the determining factor or "Form." Matter (*Materia prima; Prothyle*) cannot exist by itself. On this point in the early days of scholasticism there was some dispute, as more than one of St Thomas' predecessors held that it was capable of independent existence. Albertus Magnus and his pupil St Thomas took the opposite view, and it is that view which has held the field ever since, and still holds it. Matter, accordingly, is passive, homogeneous, incomplete, the principle of change; it is neither "being" nor "not-being," for "being" connotes the principle of actuality. It is not eternal, though in some sense Aristotle had held that it was. St Thomas taught that reason alone could not disprove the possibility of the creation by God from all eternity of some kind

* Full discussion of these teachings will be found in the different manuals of the Stonyhurst Series; in the different articles appropriate to the various divisions of the subject in the *Catholic Encyclopædia,* and in the *Manual of Modern Scholastic Philosophy*, edited by Cardinal Mercier, published by Kegan Paul, in an English translation by Frs. T. L. and S. A. Parker, to which the attention of readers may be specially directed.

of matter unendowed with motion and, of course, not self-existent. The introduction of motion sets time going, and St Thomas shows by reason that motion cannot be eternal.

According to Christian Revelation the material universe was not created from eternity—let us note in passing that here we have an excellent example of the two kinds of truths over the acceptance of which so much confusion, as we have already pointed out, has arisen. **Matter** Matter is eminently plastic, and has been called "a storehouse of potentiality," but its plasticity has its limits: "a thread of wool will not make a saw," as Aristotle pointed out. But its plasticity has to be put into **Form** operation by the second factor, namely, Form. This is the determining factor, and is the constitutive cause of everything; the principle of its intelligibility; the source of its activities; the seat of its direction.

Or we may put it in another way:—

It is the Principle of—

Being—for it determines primary matter.

Action—for it is the foundation of the body's activities.

Finality—for it controls its properties.

This Hylomorphic theory embraces both the inorganic and the organic worlds, and as regards the former, with which we are only

incidentally concerned in this book, it may be said that each simple body or chemical compound or whatever the non-living object may be, is regarded as a being endowed with substantial unity and consisting of the substrate-*matter*—with the appropriate determining factor-*form*. It may not be amiss for a moment to consider how very closely this scholastic view of matter, in the sense of Physics, *not* "Matter" or *materia prima* of the Schoolmen, approximates to the theory upheld to-day by many physicists. If, as they hold, all matter consists of vortices or kinks in ether, so that it is all modified ether existing in and interpenetrated by unmodified ether—the one being to the other **Ether** like the knots in a piece of string, as Sir Oliver Lodge puts it—then their view is very nearly that of scholasticism. Very nearly, but not quite; for the physicists allow independent existence to ether which the Thomists do not allow to "Matter." Their predecessors did, and their view is, therefore, practically indistinguishable from that of many modern physicists. According to modern Thomists, ether—unmodified ether—would have its own "Form," which would be changed for another "Form" when and as it became modified. It is interesting, even startling, to find these theories, thought out centuries ago, which approximate

so closely to the most recent speculations of men of science. It is with the kingdom of life, however, that we are specially concerned, and to this aspect of the question we must now turn our attention. There is a common "matter," the same substrate in a block of lead or a dancing fire-fly, but a different "form." The block of lead may be looked upon as a whole or, perhaps more reasonably, as a mass of molecules, each with its form, accidentally collected together. If we treat the lead with an acid—say acetic—acetate of lead (sugar of lead) is produced and a new "form" evoked. This is also a substantial unity, but the scholastics teach that it bears within itself the forces, though in a modified form, of its component elements. Each such component is an integral part of the compound, surviving there in virtue of certain properties. Thus, whilst part of the original "form" vanishes, as so many movements vanish and pass away, some remains, as we might say, dormant and hidden, but capable of resuscitation under appropriate circumstances. So far we have been dealing with *substantial forms*, which make a being what it is *i.e.*, lead or a fire-fly, but there are also *accidental forms*, which make a thing such-and-such, without constituting its essence-size, colour and the like,

Various forms

and some of these—such as the yellowness of gold—may be inseparable properties of the being in question. In connection with these two kinds of forms, those who are not close students of the scholastic system are apt to become confused as to mediæval ideas. For example, I find the following passage in one of the most suggestive books any one could wish to read, by Professor Soddy.* Dealing with Alchemy, from which Chemistry arose, during what he calls the Dark Ages—which were by no means as dark as many would have us believe—he says: "If the qualities of things are regarded as more fundamental than the things themselves; or if things are looked upon as having no existence apart from the qualities which they possess, the transmutation of one element into another appears very much the same as any other kind of chemical change." Much virtue in your "if"! There is nothing more fundamental in scholastic philosophy than its search for the underlying reality stripped of its "accidents," one of which is colour, and they would never have argued that because you can change the colour of copper by adding tin and thus produce brass, which resembles gold in colour, you could change other qualities and thus finally arrive at gold. These men

* *Matter and Energy*, Home University Library.

were not shallow reasoners, as anyone who sets himself to the study of their works will very soon discover, and their line of argument was perfectly definite and perfectly logical. Copper —they would argue—consists of *materia prima* and its appropriate form; so does gold consist of *materia prima* and *its* appropriate form. Why, since forms *can* change, may it not be possible to cause copper to lose its own form and assume that of gold and thus incidentally enrich the experimenter? Modern physicists tell us that gold is a knot in a string of ether; copper is another kind of knot in the same string. Why should it be impossible to untie the latter and retie it as the former? In fact, is not a good deal of modern research being directed towards this very end; the discovery of artificial methods of performing that very operation of transmutation which it now appears that Nature—to use that personification for a moment—is daily carrying out at least in connection with the radio-active substances?

"Souls."

Returning to our subject, it may now be said that the scholastics teach that in plants there is a higher form of unity in the shape of the vegetable form or soul (*anima vegetativa*) which converts, so to speak, the plant from a collection of chemical substances into an organic unity.

A further advance is made when we come to the animal form or soul (*anima sensitiva*), where we come to a higher unity—the unity of sense-consciousness. This form or soul is "totally immersed in matter," to use the scholastic phrase, and disappears with the death of its possessor. But it is a synthesis of the body and makes a morphological and physiological unity of what would otherwise be a group of united but un-coordinated factors.

The human soul

Finally, we arrive at the highest "form," the soul of man (*anima rationalis*), by virtue of which man not only perceives but conceives; through which things have to him a *meaning*. Of this it need only here be said in order to complete the present synopsis, that this kind of soul is simple and unextended like the animal soul, but is also spiritual and—unlike any other kind of "form"—capable of independent existence, since its essence (*esse*) is independent of matter. Thus it is held to be closely similar to the *forma subsistens* attributed to Angelic beings but not absolutely identical, since there is in the human soul an inclination or aptitude for its body. But, in comparison with the animal soul, the human is not "completely immersed in matter," but —to put things very crudely—somewhat pro-

jects from it or has something left over after it has dealt with matter, and is immortal, being incorruptible.

Such are the theories, and in the eyes of many they will appear to be "pure mysticism," "rank metaphysics," and other things which it would appear are to some men professing to be men of science, not merely puerilities but things to create laughter. On this it may be said that the man who sets out to give a real *explanation* of anything with the express determination of doing without metaphysics may as well save himself the trouble of his journey and stay at home, for he will never attain his end. He may, as many a writer has done and, doubtless, many another will in the future, build up a system, and, having assumed that it is correct, explain most beautifully and convincingly everything within that system.

But he will none the less have *explained* nothing until he has accounted for his system, and that is precisely what no one has ever succeeded in doing or will ever succeed in doing without appealing to the much abused and unfairly derided subject of metaphysics—mystical or non-mystical.

NOTE—To discuss the various problems connected with the human soul would require more

space than is possible in this book, and would lead us far beyond its scope and intention. Those who desire to study that subject may be referred to the late Fr. Maher's *Manual of Psychology*, in the Stonyhurst series, or, if they prefer a work by a non-Catholic author, to McDougall's *Mind and Body*, wherein they will find a most interesting and profound study of the whole matter.

CHAPTER IV

THE CELL

Its Parts — Protoplasm and its Characters — Nucleus — Chromosomes—Relations of Nucleus and Cell Protoplasm.

In 1651 William Harvey, the great English naturalist and physician, in his work *De Generatione Animalium*, laid down the axiom *Omne vivum ex ovo*. This generalisation has since been shown to have lacked complete accuracy, since certain living things propagate themselves by fission. But if we alter it to read *Omne vivum ex vivo* we arrive at a statement which is now generally accepted by the scientific world, though it has been strenuously opposed and is still contested by a few as will be more fully described in the chapter dealing with abiogenesis. Second only in importance to this generalisation is that which Virchow proclaimed in 1858, *Omnis cellula ex cellula*.*

* The Cell-Theory was first enunciated by Theodor Schwann, a German, but successively Professor at Louvain and Liège (1810-1882), and the honour of being its father must ever remain with him. Nor must his co-worker, Schleiden, be forgotten, but the fact remains that Virchow played a very great part in securing its universal recognition by his pathological theories and his other writings.

From that time the study of the cell has absorbed the attention of scores of workers and especially of late years has developed an enormous literature entirely its own. Nor is this wonderful when one remembers the remarkable results which have followed upon this discovery. The theory, it may fairly be said, first formally laid down as a principle by Virchow in the work which revolutionised pathology is the foundation of all modern knowledge in that subject. It was through this discovery that the common plan of organisation of plants and animals first became evident. It is through it also that we have arrived at an understanding of the processes of fertilisation and of development. It is clear, therefore, as Wilson * says "that the key to all ultimate biological problems must, in the last analysis, be sought in the cell." Von Bunge points out that it is no simple exercise which we set ourselves when we proceed to endeavour to unravel its mysteries. "When," he says, "with the help of scalpel and microscope, we have dissected the organism to its last shred, when we are concerned only with the single cell—then the greatest riddle still lies before us. The single

* *Op. cit.*, p. 1.

cell, the formless, structureless, microscopically small drop of protoplasm—it shows all the essential functions of life: nourishment, growth, reproduction, motion, sensation—yes, even functions which at least compensate for the 'sensorium,' the conscious life of the higher animals."

The cell is indeed a very small object of study. The tiny mass of protoplasm, though we now know that it is by no means structureless, would seem to the casual observer to be an object whose possibilities must soon be exhausted. Yet the more microscopes are improved, the more methods of staining and of observation are perfected, the more the cell is studied, the greater are the mysteries which it is found to contain. Again we may quote from Wilson, the highest authority on this subject, who expresses the opinion that "the recent advance of discovery has not tended to simplify our conceptions of cell-life, but has rather led to an emphasised sense of the diversity and complexity of its problems."

Schwann, when he first enunciated the cell-theory, thought that he had disposed of the question of vitalism once for all and in a sense contrary to that theory of life. But Schwann was mistaken and the theory on which he based his conclusion has since been shown to

be incorrect. What Schwann did was to shift the question to a smaller region, but in doing so he by no means made it an easier question to be solved.

Since then the cell is the basis of all bio-

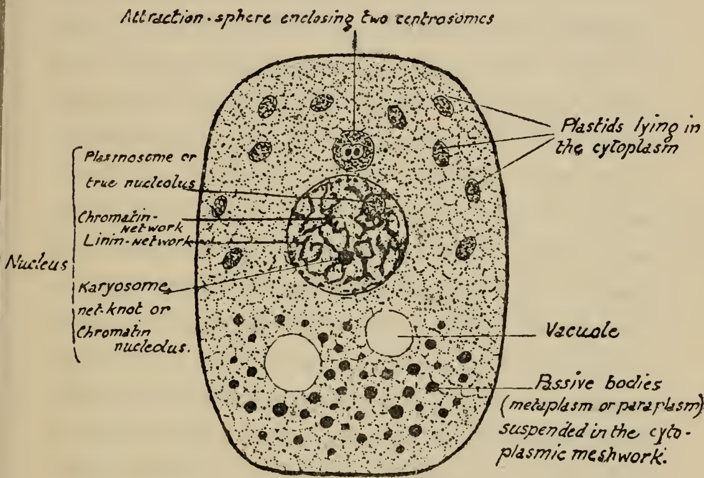


Diagram of a cell. Its basis consists of a meshwork containing numerous minute granules (microsomes) and traversing a transparent ground-substance. From Wilson.

Fig. I.

logical inquiries it will be well for us to commence our quest by briefly considering its characters and structure.

The cell (see Fig. I), speaking in the most

general terms, is a small spherical mass of protoplasm containing a nucleus or specialised central portion.

Protoplasm Protoplasm, a term first used by Purkinje in 1840 is a viscid albuminoid substance like the unboiled white of an egg. It was well described by Huxley as "the physical basis of life," and there can be no doubt that it is "the immediate substratum of all vital activity." To attempt to enter into any complete description of this most important substance would be impossible, even if it were advisable in a work of this character, but the following points, at least, must be made clear. In the first place whilst we can watch the movements of and in living protoplasm under the microscope, we cannot stain that protoplasm or still more examine it chemically without killing it and thus, it is highly probable, fundamentally altering its characters. So that when one reads about the chemistry of protoplasm, or about certain things in the cell which are studied by the aid of chemical re-agents, it is always important to remember that it is dead protoplasm and a dead cell which we are reading about, and that in that fact lies the possibility of a fundamental fallacy. With this reservation then we may say that protoplasm is composed of relatively few chemical elements.

It contains carbon, which we know of, under one of its forms, as charcoal. It contains hydrogen and oxygen, two gases which enter into combination to form water, and it contains nitrogen, another gas which with oxygen makes up most of the air which we breathe. These four substances are its most important constituents, but in addition to this there are minute quantities of other elements, notably phosphorus. It is not to the number of elements contained then that protoplasm owes its complexity. But there can be no doubt that the molecule of protoplasm, if indeed it is in any way correct to say that protoplasm has a chemical molecule, must be one of enormous complexity. Again, however, it must be insisted that we know not what may be the actual state of affairs in living protoplasm, indeed there is some reason to think that the composition of the protoplasm in one part of a cell may differ from that in another part, whilst that cell is alive. "Protoplasm," says Wallace,* "is so complex chemically as to defy exact analysis, being an elaborate structure of atoms built up into a molecule in which each atom must occupy its true place, like every carved stone in a Gothic Cathedral." Pflüger, too, a very distinguished German

Has protoplasm a molecule?

* *Man's Place in the Universe*, p. 199.

physiologist, tells us that living proteid or protoplasm is a huge molecule, undergoing constant, never-ending formation and decomposition, and gives us an illuminating view of its characters when he says that it probably behaves towards the usual chemical molecules as the sun behaves to small meteors. The fashion of speaking of protoplasm as possessing a molecule takes its origin from the extreme chemico-physical method of viewing life and living matter. It is of course possible to set down the chemical composition of protoplasm and construct a formula for it, but to talk of protoplasm as having a molecule in the same sense that—say methane—has, always seemed to be philosophically absurd, and now that biological science proclaims that "many of the properties of the cell may be carried out by isolated parts of the cell," * it is shown, I think, to be perfectly untenable. That protoplasm is a vastly complex substance everyone must freely admit.

"Molecule" of protoplasm

Much attention has been devoted to the solution of the question of the structure of protoplasm, but so far, it must be admitted, without any definite results.

The cell is generally included by a wall, and

* Moore, *Origin and Nature of Life*, Home University Library, p. 80.

if the unscientific person wishes to obtain a rough idea of what it is like he may imagine a child's toy air-balloon filled with unboiled white of egg. In the centre of this white of egg let him suppose that there is floating a small bladder as big as—say—a Tangerine orange, and that inside this sphere are some tangled skeins of tape floating in a further mass of unboiled white of egg. He will then have constructed a mental model of a generalised cell. The air-balloon will represent the cell wall and the white of egg within the cell-protoplasm or cytoplasm. The contained sphere will represent the nucleus and the skeins of tape the chromatin skeins which it contains. The nucleus is generally—though not at all times—included in a nuclear membrane which is to it what the cell-wall is to the cell. Within this membrane is a reticulum or network, a ground substance or nuclear sap and aften one or more nucleoli.

Nucleus

Of all these portions the most essential is the reticulum which consists of two parts, a general protoplasmic basis, or linin, which closely resembles cytoplasm, and a second constituent, known, from its faculty of staining deeply with certain re-agents, as chromatin. There are some who maintain that the interstitial protoplasm is the most important part of the

Chromatin

nucleus, but the great weight of scientific opinion at present inclines to the view that the chromatin fragments are the essential part not only of the nucleus but of the whole cell.* It seems as if it were the only part of the nucleus which is specifically sorted out so as to be handed on from cell to cell, and it also seems that it has the power of producing all the other elements of the cell. It consists of a number of small bodies which are called chromosomes and in the division of cells—of which fuller details will shortly be given—these chromosomes are evenly divided between the mother and the daughter cells.

The nucleus then would appear to be the most important part of the cell and the chromosomes are the essential part of the nucleus. Slightly to anticipate matters which will be made more clear in another chapter, it may here be said that in addition to the two axioms laid down at the commencement of this chapter we are now in a position to accept a third, laid down by Flemming in 1882, *Omnis*

* Without in any way exhausting this important controversy, it may be noted that whilst some have confined the heritable factors (taken as material) to the chromatin, others think that cytoplasm is also concerned in this, and some would attach those factors which are inherited on Mendelian lines (it being held by them that all are not) to the one and the non-Mendelianly inherited to the other. The matter is still quite unsettled.

nucleus e nucleo and even a fourth, postulated by Boveri in 1903, *Omne chromosoma e chromosomate*, for we know that as living thing comes from living thing and cell from cell and not otherwise so nucleus is derived from nucleus and chromosome from chromosome and also not otherwise.

Relations of nucleus and cell

But though the nucleus is the essential part of the cell and its chromosomes are the most essential factor of the whole structure it does not follow nor is it the case that the nucleus or its chromosomes are self-sufficing. This has been proved by direct experiment. It is possible for the skilled manipulator to deprive a unicellular organism of its nucleus. What happens? The cell—thus emptied of its most important part—does not immediately die. For a time it will go on exhibiting what we shall shortly learn is one of the most important and characteristic activities of life, namely irritability. But it has lost, and that permanently, all its former powers of assimilation, of growth and of repair. It is not dead but it is dying and nothing can hinder or delay its final death. Hence, as Roux and others claim, and it seems justly claim, the nucleus is the controlling agency in the cell.

But, on the other hand, if the cell cannot get on without the nucleus, neither can the

nucleus get on without the cell, for it too perishes if it be cut off completely from it. It seems as if the cytoplasm, or cell-protoplasm in some way acts as a stimulant to the nuclear protoplasm and hence, though the nucleus is, or appears to be, the main factor in division, it is possible that the cytoplasm may "indirectly regulate the process of cleavage." *

Cytoplasm then is necessary to nucleus and nucleus to cytoplasm. If a unicellular organism be so divided up that certain of the fragments into which it is separated contain portions of the nucleus and certain do not, those fragments which contain bits of the nucleus will continue to live and what is more will gradually reconstruct themselves so that each of them will become a new organism. But not so the bits which have not been fortunate enough to secure a fragment of nuclear substance. As above stated these portions linger for a time with some of the signs of life but ultimately die.

Balbiani

Hence we may conclude with Balbiani † that "the cellular life neither resides exclusively in the protoplasm [*i.e.*, cytoplasm or cell-protoplasm as opposed to nucleoplasm] nor within the nucleus, but results from the reciprocal

* Morgan, *The Development of the Frog's Egg*, p. 128.
† *Annales de Micrographie*, 1893.

relations which are established between these two elements. Isolated one from the other, neither of them is capable of life by itself."

The various structures which have thus briefly been passed under review are the main constituents, not only of the unicellular organism, but also of all living cells, whether they be gland, nerve, muscle or bone cells. Each of these specialised cells, however, has its own peculiar powers and duties and its own characteristic features. In addition to the structures mentioned, a cell may contain fatty substances, vacuoles or cavities containing fluid and even crystals.

Having now studied the appearance of the cell as it presents itself to us under the microscope it will next be necessary to consider the characteristic activities of which it is the seat, and to inquire in how far these resemble the behaviour of inorganic substances and in what ways they differ from them.

CHAPTER V

CHARACTERISTICS OF LIVING MATTER

Amoeba—Motion—Irritability—Assimilation and Metabolic Processes—Respiration—Reproduction—Death.

MANY pages could be devoted to a list of the various definitions of life which have been given by different writers, yet none of which has met with full and complete acceptance. But though the final definition is still to seek there are certain characteristics of living matter recognisable by all, which must now form the subject of our inquiries.

Suppose we take the case of the unicellular

Amœba

organism known as Amoeba,* a creature somewhere about 100th-inch in diameter and nearly conforming to our notion of the generalised cell, since it consists of an outer coat or ectoplasm, an inner granular protoplasm, a nucleus and

Motion

a contractile vacuole.

If we watch this lowly creature we may first

* For a fuller account see Hartog, "Protozoa," in *Cambridge Natural History.*

of all notice that it moves (see Fig. II). It does this by pushing out a fragment or projection of its own body and then drawing the remainder up to the promontory which has been put forth. Thus it is able to move itself

Amœba, showing clear ectoplasm, granular endoplasm, dark nucleus, and lighter contractile vacuole (From Verworn)

Fig. II.

from place to place. But beyond this we may observe the granules which generally exist in the protoplasm to be also in movement. We can see that these "stream constantly forwards along the central axis of each process as it forms, and backwards within the clear layer all round, like a fountain playing in a bell-jar." *

So that the movements take place within the

* Hartog.

creature and it is also able to transport itself from place to place. Further, if we set up a current in the water in which the amoeba is floating we shall find that it always moves against that current. This is a function of most unicellular forms and of more highly organised creatures as well, for water-fleas and other small crustacea will swim away from the fluid which is rushing into the pipette designed to capture them. It is clear that this disposition to swim against the stream must be of considerable advantage to the amoeba in keeping it in its place in spite of the natural and ordinary currents in the water in which it may be living, or those other adventitious currents which may set up from time to time by the passage of other creatures or by other means.

The living object moves

This power of being able to move itself is one of the most prominent and striking differences between the living creature and the non-living substance, and it was seized upon by St Thomas Aquinas for his definition of a living thing. Thus he defines it: "Illa proprie sunt viventia quae seipsa secundum aliquam speciem motus movent";* and again, "Ens vivum est substantia cui convenit secundum suam

* *Summa Theol.*, 1a, 9, 1, art. 1 c.

naturam movere seipsam.'* But it must not be supposed that in making this definition, which is a natural one and the most accurate yet arrived at, St Thomas was treating only of the movement of transportation. His intention, as Mercier† makes quite clear, was to take movement as the synonym of action, or more rigorously of any kind of action which involves a change. "Entre la simple aptitude au mouvement ou la pure puissance, d'une part, et le fait actuel qui suppose l'aptitude satisfaite ou la puissance réalisée, d'autre part, il y a la mise en œuvre de la puissance, son exercise, la réalisation du fait, c'est lá le mouvement proprement dit. C'est l'acte de quelque chose qui n'est pas complet, dit saint Thomas 'actus imperfecti,' ou, comme s'exprimait Aristote,‡ 'c'est l'acte d'un etre en puissance, en tant qu'il est encore en puissance.' Pour que l'esprit conçoive le mouvement, il faut qu'il ait simultanément en vue une double relation du mobile, l'une avec une puissance déjá réalisée, l'autre avec un acte encore réalisable le mouvement est tout á la fois la réalisation d'une certaine potentialité, et l' acheminement vers un acte ultérieur plus com-

* *Ibid.*, la, 9, 18, art. 2 c.
† *La Definition Philosophique de la Vie*, Louvain, 1898, p. 60.
‡ *Physic.*, v., l.

plet, c'est donc bien l'acte d'une puissance encore en puissance." *

Irritability

In the second place if we watch the amœba we shall find that it is capable of responding to certain stimuli, such as a touch, to which it replies by contracting itself and by drawing in any projections which it may have thrust out from its body. This property of "irritability" is one of the most remarkable which is possessed by living matter. It was defined by Claude Bernard as being the property possessed by the protoplasm of every anatomical element of being stimulated to activity and of reacting in one particular way to the external stimuli to which it might be submitted. What happens in this case of irritability is that some of the internal energy of the amoeba is transformed from the potential to the kinetic state and that in "response to an action of itself inadequate to produce it; and has been compared not inaptly to the discharge of a cannon, where foot-

* This is not the place to discuss so large and complicated a subject, but it may here be mentioned that the whole question of motion as related to living and not-living beings requires restating in view of modern ideas of an ultra-physical nature relating to the above and intra-atomic activities and to molecular movement. In fact, as Père de Munnyck, O.P., seems to have been the first to point out, (C.R. La congrès scientific tenu à Fribourg, 1897: *Sciences Philosophiques*, p. 450), Hylomorphism must in various ways be accommodated to these modern conceptions of the above.

tons of energy are liberated in consequence of the pull of a few inch-grains on the trigger, or to an indefinitely small push which makes electric contact: the energy set free is that which is stored up in the charge." *

Assimilation

Thirdly, the amoeba may be observed to feed and this it does by putting forth processes of its body wherewith it surrounds any particle of food which may be in the water around. Having accomplished this it then dissolves the particle or such portions thereof as are available for its purpose, utilises the dissolved material for the re-building of its tissues and the replenishment of the energy which it has expended in its various actions and casts out the useless refuse from its body. In some manner or another all living bodies and all living cells must be fed; must change their food into the materials suitable for their own use and must get rid of waste and superfluous portions. In this brief statement is included the whole vast science of physiological chemistry, even to glance at which would be impossible in this book. Speaking in the most general manner it may be said that these metabolic changes, as they are called, are of two kinds. On the one hand less complex and more stable substances are built up into other

Metabolism

* Hartog.

substances of diametrically opposite character, they being more complicated in their nature and less stable. During this "anabolic" process energy is absorbed.

And on the other hand there is the reverse process called "catabolic," in which these unstable, complex substances are broken up into simpler and more stable matters, a process accompanied by the giving out of energy. Further one must remember that the chemical processes which take place in a cell may be looked at, from quite another point of view, as dual. There are the processes which are carried on for the renewal of the cell itself and for the maintenance of the various energies of which it is the seat, and this is true whether the cell is isolated—a unicellular organism—or whether it is one of many as a portion of a multicellular organism. But, secondly, in many cases other substances, which we may speak of as bye-products, are constructed in the course of the operations carried on in the cell-laboratory. These bye-products do not appear to be of primarily or indeed of any importance to the cell, and may be actually injurious to it if retained, yet they are or may be highly beneficial or even necessary to other parts of the body, or in other cases they may be of high value to other living creatures, wholly uncon-

nected with the organism which has produced them.

As an example of the first kind of substance one may instance the bile which is secreted by the liver cells or the pancreatic juice or a number of the other internal secretions, such as those of the thyroid body or adrenals, most, if not all of these being of prime importance to the well-being or even existence of the body, but none of them being of first importance to the cells concerned themselves so far as we know.

Bye-products

The second group of excretions includes the various vegetable oils, and substances such as musk in the animal kingdom. As to these it is difficult, if not impossible, to say that they are of no service to the plant or animal which produces them, and it is only their great value to us which makes us look at them more from our point of view than from that of the organism which produced them. But, at any rate, it is quite clear that the various excreta are got rid of because they are of no further use to the animal excreting them, yet they may be of great service for purposes of fertilising the soil.

Finally, as regards this question of nutrition and digestion, the result of this taking in of food, and of the changes which take place in

it, is an increase in size always, however, within certain limits peculiar to each species, very wide limits in some cases but still definite limits, so that one can always say of any given species that it will not exceed a certain size or fall below a given limit.

Respiration Respiration is a process closely associated with those which we have been considering. This consists essentially in the elimination of the superfluous carbon dioxide produced by the operations of the body and the introduction of oxygen by which the carrying on of further such processes is rendered possible. Thus in the human being where, as in all creatures with red blood-corpuscles, the process is carried on by those cells, the expired air contains about 3.5 per cent. of carbon dioxide and 17 per cent. of oxygen, the former being about 3.2 per cent. more and the latter 4.0 per cent. less than the amount contained in the inspired air. We cannot see the process of respiration taking place in the amoeba but we must suppose that the interchange of gases which constitutes this process takes place all over the surface of the creature.

But if we cannot see the respiration taking place there is one further very remarkable phenomenon which we can study and that is the process of reproduction. In the amoeba

this consists of a division, first of the nucleus and secondly of the whole cell into two portions, so that where there was previously but one amoeba, now there are two. It is obvious that in such a case it is impossible to speak of mother and daughter, since both cells might lay claim to either title, each representing one half of the original cell. Some such process of multiplication takes place in all living things, but this important matter is one which will require fuller treatment in a succeeding chapter.

Reproduction

Death

Last scene of all which ends this strange eventful history, the amoeba may die. Weismann teaches that the unicellular organism is potentially immortal, and indeed there seems to be no reason why an amoeba should not go on living for an indefinite period, unless we regard the time when a given amoeba divides into two new forms as being really a period or moment of dissolution and recreation. But, at any rate, it is quite clear that we can kill an amoeba by a strong current of electricity, by exposing it to a temperature higher than it can bear, or by mixing certain chemicals with the water in which it lives. Under any one of these circumstances the amoeba dies, that is the living substance of which it consisted becomes not-living and the oxygen and other chemical sub-

stances which had up to this moment been its slaves now become its masters and destroy it. "This change is associated with alterations in the mechanical and optical properties of the protoplasm, which loses its viscidity and becomes opaque, having undergone a process of *de*-solution; for the water it contained is now held only mechanically in the interstices of a network, or in cavities of a honeycomb, while the solid forming the residuum has a refractive index of a little over 1.6. Therefore, it only regains its full transparency when the water is replaced by a liquid of high refractive index, such as an essential oil or phenol. A similar change may be effected by pouring white of egg into boiling water or absolute alcohol, and is attended with the same optical results." *

Such, then, are the chief characteristics revealed by our study of the amoeba. It moves, it responds to stimuli, it breathes and it feeds, it carries on complicated chemical processes in its interior. It increases and multiplies and it may die.

These observations are not only true of the single-celled organism but of the multicellular and they are equally applicable to the animal and to the plant.

* Hartog.

Perhaps, however, it may be right to call the attention of those unaccustomed to consider biological problems to the difference—apart from all question of multitude or number of cells—which exists between the unicellular and the multicellular organism. In the former case all the functions which the animal performs are carried out by the single cell. To put matters plainly this one cell is brains, lungs, heart, stomach, intestines and reproductive mechanism. In the multicellular organism there is a division of labour, so that whilst there are many more cells, each of them is capable of doing less work or a lesser variety of work than the single cell of Amoeba. We may compare the conditions exhibited by the two to the older and the newer conditions of mechanical labour. In olden days the artisan made the whole of—say—a watch, nowadays, he makes a pin or a screw and nothing else and knows and perhaps cares nothing about what the pin or screw is for or how it affects the operations of other workmen.

Moreover in the multicellular organism each cell has its own life as well as sharing in that of the whole body. It may have its birth and its death, of both of which the body as a whole is entirely ignorant.

But whether it is an isolated cell or a member

of a cell-congeries, as a part of a multicellular organism, it will exhibit the characteristics dealt with in this chapter, though, of course, in varying degree in accordance with its site and its functions.

CHAPTER VI

CHEMICAL CHARACTERS OF CELL

Crystallisation — Bye-products of Cell — Movement — Irritability or Tactism

The comparison between living bodies and a machine will form the subject of another chapter, but having proceeded as far as we have in the study of the cell it may be wise to pause for a short time and consider in how far the facts narrated in the previous chapters tally with the conditions obtaining in inanimate nature and how far the two categories are at variance with one another.

Chemistry of living matter

In the first place it may safely be said that the chemical constitution of living matter, as far as we know it, does not in any way help us to understand its possibilities. As we have seen, we gain an idea of enormous complexity of composition, but that complexity does not begin to be an explanation of the wonderful powers of living matter. There are other highly complicated organic compounds but they do not display any beginning of vital powers nor

anything which is on the road thereto, so far as they have as yet been investigated. It is true that cyanogen was declared by Pflüger to be half-alive, but the phrase was rhetorically used, for what is really meant is not by any means what might be taken to be meant by the phrase in question. To explain the matter fully would lead one too far into the paths of chemistry, but this at least may be said that no chemist would assert that cyanogen or any of its compounds was in any way even on the road to being what may be properly understood to be a living organism even of the most lowly character.

Hertwig

Hertwig * says that the work of the investigator of the peculiar problems of life begins where that of the chemist comes to an end. "Over the growth of the chemical molecules is placed the growth of the cell, and over this again the growth of plants and animals with their unions of millions and milliards of different cells. Chemical knowledge as it exists at present has nothing to do with that new world of organised substances in which the manifestations of life are first made obvious."

The living cell, as we have seen, is composed of comparatively few elements. It derives its food from all sorts of things and from this food

* *Allegemeine Biologie*, 2te ed., 1906, s. 19.

it builds and rebuilds its own substance, bending the materials which it assimilates to its own uses and purposes. This process of assimilation is no doubt in some measure chemical, that is to say chemical changes and operations take place during its progress. But when one says so much, one is not saying that the changes are purely chemical, for such, in fact, is not the case. In the course of an ordinary chemical combination two—or it may be more—substances unite to form a third, as common salt, for example, is formed from sodium and hydrochloric acid. But the cell takes up not-living matter and assimilates it and converts it into living protoplasm. Moreover this process of growth is interstitial in its character and not superficial, in other words it is not a growth in size due to the deposition of new layers on top of the old ones, as in the case of a rolling snowball. The deposition of new material occurs throughout the entire substance of the cell, so that its increase in size is due to a general expansion of the entire organism. And herein lies a prime difference between the living organism and a crystal, forms between which some have urged that a close resemblance exists, or at least have argued that between crystallisation and assimilation there were sufficiently close resemblances to permit it to

Crystals and living things

be argued that there was no fundamental difference between the two processes. The difference just mentioned is fundamental in character and sufficient in itself to distinguish the two processes. But beyond this it may be pointed out that when a crystal is formed by the evaporation of the solution of some salt, say the sulphate of copper which is formed into the huge blue crystalline masses often exposed in chemists' windows, what happens is that particles of an identical chemical character come together and take up—for reasons, it must frankly be admitted, of which we are entirely ignorant—the characteristic form or any of the characteristic forms of the substance which was in solution. So that a crystal is a mass of homogeneous particles, collected together and built up into a regular edifice. Suppose we add new material to this, with a view to increasing the size of the edifice. All that happens is that new material of a precisely similar character is added layer by layer to the surface of the old, and this new material must be identical in character with that to which it is added. But in the cell, not only is the addition not layer by layer but interstitial and intimate, but also the substances which are taken in are moulded to the purposes of the cell and are broken up and

converted into the very substance of the cell itself or into bye-products of one kind or another. Of this production of bye-products more must be said in a further paragraph, but before passing to the general question, it may be well, as we engaged upon the topic of crystallisation, to point out that some living organisms do construct crystals within themselves so that if the parallel between crystallisation and assimilation were a fair one we should be confronted with the somewhat bizarre fact that one kind of crystallisation was making use of another for its own purposes.

Living crystals

The facts, moreover, which have been brought forward by Professor Minchin * show not only how different the two processes are but also how the living cell is able to modify the process of natural crystallisation for its own purposes. He says: "An ordinary crystal owes its peculiar characteristics entirely to the action of the laws of inorganic matter, laws which admit of being accurately formulated and accurately calculated. Crystalline bodies are, however, known to occur which have been deposited within living bodies, and which owe their origin to vital activities. In such cases, the crystals, while identical in their chemical com-

* "Living Crystals," *Proc. Roy. Inst.*, vol. xv.

position and molecular structure with crystals of inorganic origin, may exhibit, at the same time, certain peculiarities which are due entirely to the circumstances of their origin. . . . The relation of the spicules to the structure of the sponge shows that they have a definite function to perform and an important part to play in the economy of the organism which produced them. . . . We may, therefore, sum up in regard to the living crystals as follows—their composition is that of calcite crystals, but their external form is that which the sponge requires, and not that which they would naturally assume. They furnish us, in fact, with a beautiful instance of what is called adaptation; that is to say, the fact that any living organism tends to have just that form, structure and organisation in all its parts which it requires in order to maintain its existence in its peculiar mode of life, whatever it may be."

Professor Joly, in an article entitled "The Abundance of Life," makes the following important statements concerning this matter:—* "It is necessary to observe on the fundamental distinction between the growth of the protoplasm and the growth of the crystal. It is

* *The Birth Time of the World*, Fisher Unwin, p. 74.

common to draw comparison between the two, and to point to metabolism as the chief distinction. But while this is the most obvious distinction the more fundamental one remains in the energy relations of the two with the environment. The growth of the crystal is the result of the loss of energy; that of the organism the result of the gain of energy. The crystal represents a last position of stable equilibrium assumed by molecules upon a certain loss of kinetic energy, and the formation of the crystal by evaporisation and concentration of a liquid does not, in its dynamic aspect, differ much from the precipitation of an amorphous sediment (*in a footnote it is stated that* 'it appears exceptional for the crystalline configuration to stand higher in the scale of energy than the amorphous'). The organism, on the other hand, represents a more or less unstable condition formed and maintained by inflow of energy; its formation, indeed, is often attended with a loss of kinetic energy (fixation of carbon in plants), but if so, accompanied by a more than compensatory increase of potential molecular energy."

Finally, as regards the question of crystallisation, the crystal of any rock can be dissolved and will re-crystallise under suitable conditions, and these two processes can be repeated *ad*

infinitum. But the living cell once destroyed cannot be reformed, another fundamental difference between the two.*

Bye-products of cell

The question of bye-products is one which has been already touched upon more than once; and what a remarkable series of bye-products there are when one contemplates the vegetable world alone! There are the numerous alkaloids and essential oils which are so much used in medicine and in the arts, the essences with which perfumes are made, waxes, turpentines and a whole host of other compounds all constructed by the cell in its own laboratory and out of the comparatively few elements, for the greater part four or five only, with which it works.

Yet all the time that the cell is doing this, all the time that it is breaking up and rebuilding its own substance, whilst it is concocting in its internal manufactory the bye-products of which we are speaking, all this time the cell remains unaltered or unaltered save in immaterial characteristics. It is the same cell,

* For a full examination of the question of the growth of living things and of crystals see Johnstone, *Philosophy of Biology*, pp. 168 *seq.* "It is inexplicable to me" (says de Quatrefages (*Les Emules de Darwin*, ii., 63; *teste* Gerard, *Old Riddle*, p. 64), "that some men whose merits I otherwise acknowledge, should have compared crystals to the simplest living forms. . . . These forms are the antipodes of the crystal from every point of view."

Alter et Idem

though all its constituents may have been changed. Just as our bodies remain our bodies, though the constituents of which they are composed are constantly altering. One is reminded of the knife which was the same knife though it had had a new handle and a new blade or of the more poetical simile of Wordsworth :—

For, backward, Duddon! as I cast my eyes,
I see what was, and is, and will abide;
Still glides the Stream and shall for ever glide;
The Form remains, the Function never dies.

Chemistry then does not raise the veil which hides the secret of life, and physics is equally incompetent to do so, indeed Lord Kelvin * says that "the only contribution of dynamics to theoretical biology is absolute negation of automatic commencement or automatic maintenance of life."

Movement

Movement, which we have seen to be one of the characteristics of living things, is not, except in the form of the so-called Brownian movement,† exhibited by not-living matter. A stone on the moor will not shift its position

* *Properties of Matter*, p. 415.

† Robert Brown, the botanist, first rescribed these movements in 1827, though he of course did not know that this curious and continual dance of fine particles (for example, of gamboge) was due to the perpetual motion of the molecules. It is not possible in this book to deal with the very abstruse problems of intra-atomic and molecular movement (see footnote on p. 66). The movements dealt with in the text are movements of transport; self-initiated and carried out.

unless the wind or the rain or the action of some other force cause it passively to be moved. Atoms of non-living material thrown into water will sink or swim according to their specific gravity, and if they are capable of floating they will be borne down stream or hither or thither as the currents in the water may determine. But the living animal, even of the lowliest character, swims, if it chooses, and it generally does choose, against the stream, whether it does this like the amoeba by the putting forth of temporary processes, or like the ciliata by the waving of tiny permanent projections, or like the fish by the aid of its fins.

Rheotaxy This tendency to move against the stream is called rheotaxy. But thus to name the capability or further to tell us that one of the characteristics of living matter is to react in this way to running water is not to explain the occurrence. Many people are satisfied if they have named a phenomenon and others are quite happy if they have restated the terms of the occurrence in fresh phraseology, but it must be quite obvious that neither of these processes helps one very far along the road which leads to an explanation of the process itself.

Let us, however, suppose for a moment, that the so-called rheotaxy is really a reflex action

set up by the running water. At any rate it falls into line with a number of so-called other taxies, such as photo-taxy or the turning of certain plants towards the light and so on.

These we must look upon as examples of the power of irritability which the living protoplasm is possessed of, a possession which Hertwig describes as its most remarkable peculiarity. Moreover * he says that irritability exhibits its specific phenomena through the special structure of the irritable substance or, in other words, that irritability is a fundamental property of living protoplasm, but that it exhibits itself, according to its own specific structure, under the influence of the external world in specific energies and irritabilities.

Does irritability exist?

The extreme school of mechanists deny that there is any such thing, strictly speaking, as irritability and with their views as formulated by one of the most recent and most able writers on the subject, M. Le Dantec,† it will now be necessary to deal.

Spontaneity of movement, he tells us, is not an essential character of life. "If we observe with no other help than what nature affords

* *Op. cit.*, S. 136.

† *Op. cit.*, p. 157. Italics in quotations from this author are as in original.

all that goes on round about us, it will seem evident that the mouse moves in conditions where a stone of the same dimension and situated in the same place would remain motionless. In other words, where the stone's immobility shows that there is no cause of movement (wind, water-current, etc), a mouse displaces itself *spontaneously.*"

The mouse and the stone

If we reasoned more closely, we should say: "Where the stone's immobility shows there is no displacing cause *for the stone*, the mouses's movement, on the contrary, should make us think—either the mouse is endowed with spontaneous mobility, or at the point where it is placed there is some cause of movement *for the mouse.*"

This no doubt is perfectly true, but the real heart of the matter is the nexus between the cause of movement and the movement itself. It is clear that the nexus might be physical, since some one might pick up the mouse and throw it away. It is conceivable that it might be chemical, since we could imagine a condition of affairs in which contact, say, with a certain gas, should set up a quasi-effervescence in the mouse which would cause movement. Or again it may be vital, that is that the mouse moves because it choses to move and is actuated to that choice by the sight of danger, by

the smell of food, by the call of another mouse or what not.

We may, of course, exclude the first form of movement, for in it the mouse is as passive as the stone and is moved in no other way than a stone when it is cast from the hand.

As regards the other or chemical explanation, one must commence by making it clear that the comparison of the gas and the effervescence used above was employed as a very rough simile, purposely rough in order to make clear the kind of series of incidents which might be postulated, but hopelessly crude when applied to a body the main phenomena in which are based on the behaviour of the colloid substances of which it is built up. Of these substances and their behaviour we at present know very little, and most people would say that to dogmatise and generalise on that little is, in the face of the many reconstructions which new facts are almost sure to entail, to say the least of it a very unwise proceeding. However that is just what has been done, and the writer in question, after dealing with the subject of tactisms, of which mention has just been made, states it as his opinion that "the *irritability* peculiar to this cell species can be thus reduced to a sum of perfectly well-defined *tactisms*" **Tactisms** (the cell in question is the antherozoid of a

fern). He proceeds: "After this *nothing* remains of the pretended spontaneity of movement in living bodies. An observer conversant with the results of all these experiments in tactisms *knows* that the movements he observes in living bodies through the microscope are due to the colloid and chemical reactions of the mobile beings and the medium." This will seem to most readers of Le Dantec's book a sufficiently wide deduction to have been drawn from the comparatively few facts brought forward. But let that pass. The quotations just given make it abundantly clear that in the author's opinion, and he may be taken as the spokesman of a certain school of opinion, there is no such thing as spontaneous or voluntary movement, but all movement is in the nature of a chemical or physical or chemico-physical reaction, and that, although we may be wholly ignorant of how this takes place, we may be quite sure, from what we know of the behaviour of fern-antherozoids and the like, that it does take place. With this summary of the views under consideration we may now return to the writer's first example. What made the stone move? It moved because some one kicked it, *i.e.*, its motion was passive. What made the mouse move? Let us suppose that it was because it saw a cat. Then its

movement was active. Not so, says M. Le Dantec, as we must suppose from the opinions which he expresses, the presence of the cat exercises a tactic influence upon the mouse which obliges it to move, but its movement is not an active one but as passive as that of the stone. As far as the present writer can see the above is a fair statement of the views now under consideration.

If this is the case, however, there is one thing quite clear, namely that the tactic influence must work always and unerringly and altogether apart from any influence which the mouse may be supposed to be able to exhibit, granting for a moment that it could, if the passive sport of tactisms, exercise any influence over itself or anything else. This at least is clear, for the rigid unbending rules of chemistry and physics would make it impossible for any departure to arise from the regular series of events involved in a chemical or physical process. We may grant that a mouse does usually or even invariably fly from a cat when it sees one. The reaction regularly occurs. But we cannot be at all sure that if a cat was introduced for the first time into an island inhabited by mice that they would fly from it. So far as the present writer is aware the experiment has never been tried. But very similar

Rigid rules of chemistry

experiments have been tried and their results seem quite fatal to the conclusions which have been set out above. Let us substitute a sea-bird for the mouse and a man for the cat. It will be granted by all that the re-actions which might be supposed to take place between the mouse and the cat might equally well take place between the bird and the man.

Seagulls

And as a matter of common observation we know that a sea-gull will not allow one to walk up to it, but will fly or exhibit the phenomenon of motion at the approach of a man. But this has not been true always or of all places. We know quite well from the writings of early explorers that when they set foot on islands where men had never previously trodden, they found the sea-birds quite tame, and instead of exhibiting a movement of repulsion it was one of attraction which took place, for the creatures waddled up to see what new thing had drifted on to their shores. All this was changed when the poor birds came to know what men were and how dangerous it was to remain long in their vicinity.

Walruses

Again, Mr Chatterton Hill in his interesting book * gives an account of the walruses in the South Sea Islands visited by German ex-

* *Heredity and Selection in Sociology*; Black, London, 1907, p. 74.

plorers in 1790. "On the arrival of the expedition, the animals were perfectly tame and fearless but advantage was taken of this to hunt them down and secure their flesh as meat for the European visitors, and by the end of the winter the animals were already difficult to approach. The following winter, when another exploring party arrived in these parts, the walrus fled whenever it perceived a human form in the distance; it had grown to recognise man as its enemy, and took refuge in instinctive flight."

Now one may fairly ask, what becomes of the theory of tactisms in these cases? Here we have a sudden change of behaviour on the part of the birds or the walruses towards the men, an alteration of a kind wholly unknown to chemistry and physics, one which can only be explained on the ground that the birds were possessed of a sense not belonging to non-living matter. The only other explanation is that the contact with man caused such an alteration in the colloids of the sea-birds' bodies that a different re-action took place after some time of acquaintance to that which was first exhibited and such an explanation only needs to be formulated for its absurdity to be seen.

We may fairly claim then that though many phenomena exhibited by living things may be

explained as tactisms, and as re-actions to certain chemical or physical forces, it is not possible to explain all the phenomena of life or of irritability in these terms.

NOTE.—It may be noted that Jennings in his work on Animal Behaviour explains all these Tactisms by Trial and Error and Avoidance Reactions. The same seems to hold of Tropism, *i.e.*, movements of plants due to unequal growth. Growth is never rectilinear but wobbles. But it tends to wobble in the most favourable course, and wobbling away from such a course is inhibited.

CHAPTER VII

REPRODUCTION

Karyokinesis — A Vital Process — Cell-Division — Is it Mechanical?—Experimental Embryology.

We have already seen that one of the leading characteristics of living things is their power to reproduce themselves; to increase and multiply. In the case of the Amoeba this process is of the simplest nature, for from the single individual are formed two new members of the race, neither being strictly speaking mother nor daughter.

In the great majority of cases and in all the higher animals and plants reproduction takes place as the consequence of the fusion of elements derived respectively from the male and the female which combine to form a single cell from which are derived, by successive divisions, all the cells, however many and however differentiated from one another, of which the adult body is built up.

In certain cases no remarkable phenomena

Karyo-kinesis

attend this process of the division of a cell into two parts, but in the majority of instances, and invariably in the case of the cell from which a new individual is to be built up, a singular series of events takes place of which some mention must now be made.

In a previous chapter the structure of the nucleus and cell in what is often called, though the term is a misleading one, the "resting stage" has been described and it will not be necessary to recapitulate the facts there laid down.

Prior to the division of the cell the linin of the nucleus, or most of it, becomes broken up into a series of threads on which the particles or granules of chromatin arrange themselves along the threads like so many beads on a

Description for Fig. III. on Page 95.

A. Resting cell with reticular nucleus and true nucleus; at *c* the attraction-sphere containing two centrosomes. B. The chromatin formed into a continuous tape, nucleolus present, amphiaster (*a*) formed around centrosomes. C. Spindle-shaped karyokinetic figure formed, consisting of two centrosomes with radial arrangement of protoplasm around each, equatorial plate (*e.p.*) of chromosomes in centre. D. The equatorial plate (*e.p.*) has split longitudinally (*n*) the cast-off nucleolus. E. The two sets of chromosomes are diverging and the interzonal fibres (*i.f.*) lie between them, the central spindle. The centrosomes are already doubled in anticipation of the next division. F. The cell-body has divided and the two groups of chromosomes are in process of reconstructing themselves into nuclei. G. Completion of the process of division. Two cells, with fully constituted nuclei and centrosomes take the place of the single cell shown in A.—*From* Wilson.

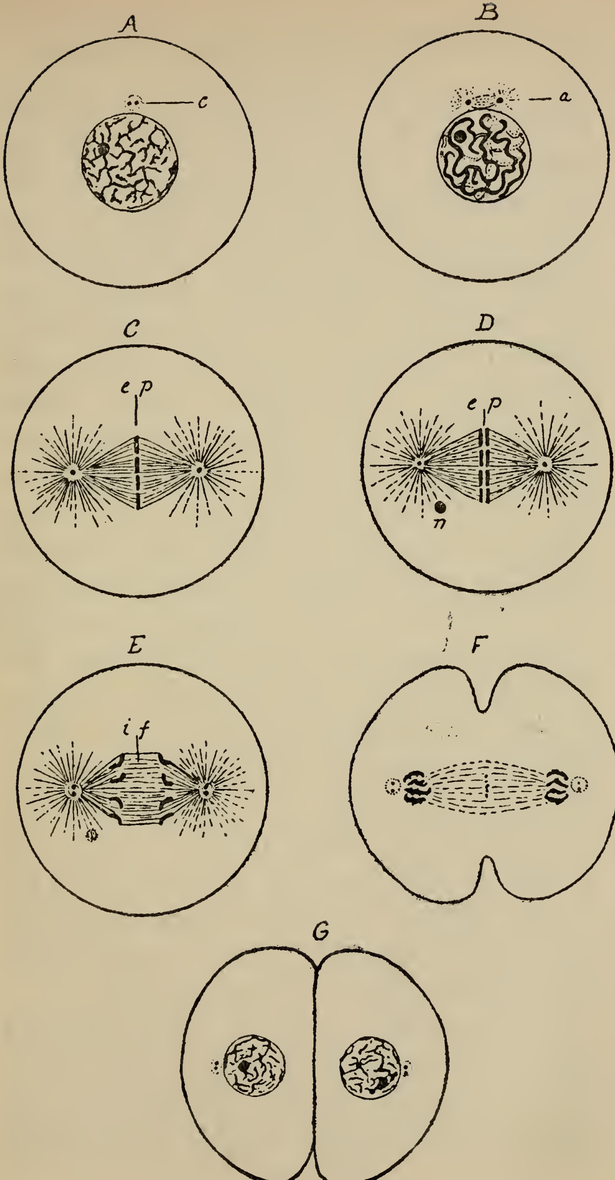


Fig. III.

string (see fig. iii.). Then each bead splits into halves and as the linin thread at the same time flattens out, the appearance comes to be that of a piece of tape along both edges of which small beads have been sewn. Then the piece of tape is split longitudinally, so that we now have two narrow bands of linin each with its single row of chromatin granules. When these processes have taken place—in many, though not in all cases—the nuclear wall disappears and two little bodies, called centrosomes, come to lie one at either side of the cell. The chromosomes, for so the linin bands with chromatin beads are called, arrange themselves between the centrosomes in such a manner as to form a spindle-shaped figure with its broadest part in the centre of the cell and its apices at either side and converging on the centrosomes. Meantime the cytoplasm, or cell-protoplasm has also been rearranging itself in the neighbourhood of the centrosomes, forming around them a series of rays, so that there are at each side of the cell two figures resembling conventional representations of the sun, between which is the spindle-shaped basket of chromosomes.

Chromasomes

The chromatin is now no longer arranged along the edges of the linin bands as it was at first, but becomes gathered together about the equator of the spindle, that is at its widest

portion which is situated at the centre of the cell.

All these events may be considered as having been preparatory to the great business of division which is now to take place. The chromatin masses, at the centre of the spindle, now become divided into two parts, each by a line of fission which is at right angles to the long axis of the spindle. Two groups of chromosomes are thus formed which we may roughly speak of as a right and a left group. Each of these now retreats farther and farther from the centre and from its sister group and approaches nearer and nearer to the periphery and to the centrosome.

It does not, however, actually reach this structure but stops short on arriving near it, so that we now find on either side of the cell a group of chromosomes situated to the inner side of the centrosome, which chromosomes as they take up this position become shorter and thicker and crowd up close to one another. A wall forms around each group of chromosomes, a new nucleus or pair of nuclei being thus constituted, and finally a wall of separation divides the two parts of the cell from one another and the process of division is complete, for where one cell alone existed there are now two. Such a process of division, accompanied

by this kind of country-dance on the part of the chromosomes, is called a process of karyokinesis or of mitosis and one can hardly dwell at all deeply on the significance of it without coming to the conclusion that a part at least of its intention is that there shall be a similar distribution of the chromosomes throughout all the cells of the body. The original cell from which the whole body is to be formed was possessed of a certain number of chromosomes, let us say eight. At the first division there occurs a halving of each of these, so that in each of the pair of cells which is derived from the original cell there will again be eight chromosomes and each of these will have a sister-chromosome in the other cell.

Distribution of chromosomes

Further, as subsequent divisions take place and the number of cells becomes enormously increased, the same process is continued, so that there are always the same number of chromosomes in every cell—of a given species—and these are derived by direct descent from the chromosomes of the original cell. These remarkable facts, which are the outcome of the intense study of the cell which has been such a prominent feature of the biological work of the past quarter of a century, are of the profoundest significance and have formed the foundations of more than one imposing edifice

of theory as to their meaning. Into these points it is not possible here to enter, but what one has to consider is the nature of the process which has just been described.

Vital or mechanical?

Is it chemico-physical in its character or is it a purely vital phenomenon? A good deal of attention has been directed to this inquiry, and particularly by Professor Hartog,* who points out that the spindle and the external radiations described above make up a "strain-figure," like that of the "lines of force" in relation to the poles of a magnet. "Such," he continues, "we can demonstrate in a plane by spreading or shaking iron filings on a piece of paper above the poles of a magnet, or in space by suspending finely divided iron in a thick liquid, such as mucilage or glycerine and bringing the vessel with the mixture into a strong magnetic field; the latter mode has the advantage of enabling us to watch the changes in the distribution of the lines under changing conditions or continued strain." From this we gather that there are at the very least strong features of resemblance between the remarkable dance of the chromosomes and operations which can be produced by means of purely physical conditions, but does this mean that

Mitokinetism

* *Op. cit.*, p. 26, for references, etc., see his paper, *Proc. Roy. Soc.*, 1905, B. lxxvi., p. 548.

the two are really identical or even similar processes? Similar, but not identical, is Professor Hartog's reply to this question. "Though," he says, "the forces at work in the dividing cell are similar in their effects to such physical forces as magnetism, static electricity, and even capillarity, and models utilising such physical forces have been devised to represent the strain figures of the cell, the cell forces are distinct from any known physical force." In other words the indications point to the fact that the remarkable happenings which have been described as taking place in the cell prior to and during division are vital manifestations, since they cannot be explained by any of the known forces of physical science.

In a later publication, in which the whole of this subject is thoroughly handled,* the opinions previously put forward, and as his views are of the first importance, these expressions may well be quoted here. "The cell-field shows the greatest analogy in its formation and behaviour to the electrostatic field between oppositely charged conductors; but (that) the force is no more electrostatic force than it is any of the known dual forces." He thinks that we are in face of a "new force" so far "unknown in the physical world of non-living

* *Problems of Life and Reproduction*, Murray, 1913.

material." This he proposes to call *mito-kinetism*, and his view—as a vitalist himself—is that the discovery of this new force leaves the vitalistic problem just where it was.

Division of ovum

We are now in a position to pass from this part of the question and to consider another of no less interest. The first division of the fertilised ovum had as a result the production of a two-celled creature. Each of these cells again divides, so that if division were always regular in its progression, which it is not, we should have the two-celled stage followed by one of four cells and that by others of eight, sixteen, thirty-two, sixty-four and so on. Such a progress of division does take place in some cases, but in others differences, as to which nothing can here be said, are exhibited. But whatever may be the sequence of division the result is the formation of a creature which from one cell has developed into a multicellular organisation. It is obvious that this multicellular organism might consist of identical cells or of cells differentiated from one another in groups so as to form different organs. Such is the condition which is met with in all the higher animals where, as, for example, in man, differentiation is carried to a very great distance. Yet even in man the cells of the brain, of the liver, of bone, muscle and skin, so

different from one another, so utterly unconvertible into one another, are all the descendants of a single cell and have been derived from it by processes similar to those described in the earlier part of the present chapter. Perhaps one may pause for a moment here to consider the bearing of these facts upon the question with which this book is concerned. The living body is often compared to a machine and is said by some to be nothing but a machine and explicable, did we know all the facts, on the same laws and principles as those whereby a machine is explained. Those who hold such views have, at least so it seems to the present writer, to encounter enormous, even insuperable difficulties, when they arrive at this subject of development; for let us grant that the cell—the single cell—is a machine for the purposes of argument. Let us even suppose that such a machine should be capable of producing, of its own mere motion, other machines like unto itself. That is a sufficiently large assumption, since no machine has ever yet been made or thought of which does anything even faintly foreshadowing what is here imagined. Nor has any chemical compound the power of reduplicating itself, by means of its own inherent forces. Suppose even that these things were believable they are nothing to what happens in

Living body and machine

the formation of the body of an animal. For here the original cell—or machine as some would have it—does far more than reproduce itself, it makes scores and hundreds of new and quite different machines. We might perhaps, though with difficulty, imagine a lathe which could beget other lathes, but here is a lathe which produces sewing-machines, organs, quick-firing guns, dredges, railway-engines and a whole host of other complicated assemblies of machinery. It is difficult if it is not impossible to believe anything of the kind. Some one has aptly remarked that if we were to fill the hull of a huge steamship with machinery as fine as that which is met with in an ordinary watch it would in some measure represent the complicated arrangements and activities of the single cell, but what must be its powers if it is capable of developing in the manner and in the directions in which we know that it can and does develop. In order to parallel what it does by chemical processes one would have to imagine a crystal, say, of the so-called microcosmic salt, since that has a tolerably complicated formula for an inorganic substance, placed in some sea water. We have then to suppose that this crystal collects to itself the necessary materials and surrounds itself with a number of crystals of other salts; collects

them into the same body; co-ordinates them and causes them all to work together for the common good; and finally splits off from itself small fragments not in any way resembling itself, from which, however, by a process of growth and development, further crystals like unto the congeries which we have been imagining are developed. Perhaps it will be said that the comparisons just made are crude and coarse and cannot fairly be taken as representing the delicate processes of nature. This may be freely admitted, but such comparisons bring out the difficulties which there are in accepting the mechanical theory of nature and, one may also say, exhibit the profound differences which exist between the inorganic and the organic worlds.

Experiments in embryology

This argument is greatly strengthened when one takes into consideration the facts which have been elicited by the experimental study of developing ova during recent years. If there is one thing which is quite clear about chemical and physical processes it is that they are rigid and unvarying. So far as we know a certain result is attained by one series of steps and by that series alone, and any interference with that series leads to a collapse of the whole process and a failure to achieve the end which would otherwise have been reached.

This is not the case in the process of development, for the egg possesses a power by which it is absolutely able to modify the course of nature and to arrive at its destination by a road never previously utilised by any egg. Some will reply that this is because the egg is adapted to reach a certain end and, therefore, does reach it. We shall have to consider more carefully the queston of adaptations in a succeeding chapter but here it may at once be said that to explain or attempt to explain the occurrences which are about to be described by that method is really tantamount to explaining them by saying that what is intended to happen must happen, which does not help us very far upon our road.

And even those who hold to the most mechanical idea of adaptations, if such a word has any real meaning in the mechanical philosophy (which may be doubted), even these will be forced to admit that adaptations in nature would naturally be provided for purposes likely to occur in the ordinary course of nature. Now steps in the experimental embryologist, and, with all the resources provided for him by science, he sets himself to work to modify and distort the course of nature. What is the result? Within limits and wonderfully wide limits, the egg gets the better of him, for it

arrives at the haven for which it set out without being deterred by the difficulties put in its way. A number of experiments of this kind have been made and will be found in books dealing with questions of this kind. One or two of them may here be described in as simple language as possible, so that the reader unversed in biological literature may be able to understand something of the weight of evidence which lies behind the argument now under consideration.

Frogs and sea-urchins

First of all then we may consider certain experiments in the modification of the development of the eggs of frogs and sea-urchins, for both behave alike under these circumstances. The course of segmentation in these cases is as well known as the route from London to Brighton and the first result of segmentation is the production of a sphere of cells from which the later organism takes its form. Now the process of this development has been modified by placing the egg between plates of glass so that it must develop under pressure. As a result of this pressure it becomes impossible for the rapidly increasing number of cells to arrange themselves in a sphere as they would naturally have done, and they are forced to develop in a plane between the two sheets of glass. If the process were to be carried on

too long the result would be the death of the developing creature from sheer want of room, so it must be released after the experiment has gone a certain distance. What then happens? The egg goes on its way segmenting as if nothing had occurred; there is no re-arrangement of the nuclei, a most significant fact; and finally a perfectly normal larva of frog or sea-urchin is the result. That is a frog or a sea-urchin has been developed by means of a series of events which one may safely say had never occurred before, a tolerably clear proof that there is within the egg a power which is able to steer it even through seas before unsailed by any egg.

A further development of this is to be studied **Neresis** in experiments made by Wilson on the eggs of Nereis, an annelid. It is a little difficult to describe this experiment without becoming highly technical, so that those who are familiar with the real facts of the case must deal leniently with the writer if he endeavours to make the circumstances clear by simplifying things to the utmost extent. In the normal development of Nereis, then, it is known that certain cells will develop into certain parts of the later organism and others into different and distinct parts.

Now if the egg be allowed to develop under

pressure as in the experiments above detailed, the lines of division are vertical in all cases, so that the segmented egg finally forms a plate, a flat plate, of eight cells. Now if these cells, thus formed into a plate, are released from the pressure under which they have been developing they at once again divide in an approximately horizontal plane, so that sixteen cells now make up the congeries. The subsequent course of the development of these shows that some of the cells with, of course, their included nuclei, which would under normal circumstances have been worked up into one part of the body, are, under the altered conditions, actually converted into another. The significance of this experiment will be obvious to any one who considers it, but that significance will be increased when it is remembered that the results negative certain views which were held as to the specific character of the nuclei. It was held by some that the nucleus of each cell was of a specific character and could produce a cell of one type and of one type only. Even if this were the case it would not have helped us very far towards an explanation of the powers of the cell, for we should still be ignorant of how the nucleus succeeded in so modifying the cell as to make it lead to the development of a liver or of some part of the

body. But this experiment (and many others of a similar kind might be cited) seems to show that the nuclei of the various cells during development, at any rate, have no specific character, but are capable, to put the matter colloquially, of turning their hands to any job in the gradually rising edifice of the body.

A third and final experiment may be quoted, of quite a different character. It was also carried out by Wilson and is corroborated by other and similar experiments on other forms.

Amphioxus

There is a little creature which lives in certain seas and is known as the Lancelet. To scientific men, and now indeed to numbers of readers who would not claim to be scientific, this creature is better known as the Amphioxus. In the course of its development the single cell of which it was originally formed divides into two-, four-, eight-, sixteen-celled stages.

Now let us suppose that at the eight-celled stage the group is put into a test-tube with water and violently shaken. The result is that the eight cells are shaken apart and become completely separated from one another. Then a very remarkable thing happens. Most people would imagine that the immature creature must have been killed by such rough treatment, but such is not the case. Each of the eight cells, undaunted by what is has been through,

sets itself to work, begins to divide on its own account and finally builds up a complete Amphioxus. Let us consider what this means. A single cell, from the eight-celled groups, would under normal circumstances have constructed, one may roughly say, one-eighth of the future amphioxus. It might have been worked up into its tail, into one of its internal organs, into a variety of portions of the body. But under the altered circumstances it is able to construct and does construct an entire and complete new amphioxus.* It was the consideration of phenomena of this kind which led Driesch, one of the greatest of workers in this line, to declare that the egg seemed to act like an intelligent being.† And the same thing is admitted by Wilson in the preface to his great work‡ where he says: "'One is sometimes tempted to conclude' was recently remarked by a well-known embryologist, 'that every egg is a law unto itself!' The jest, perhaps, embodies," he continues, "more of the truth than the author would seriously have maintained, expressing, as it does, a growing appreciation of the intricacy of cell phenomena, the difficulty of formulating their general aspects

The egg

* This experiment is of great importance in connection with Driesch's argument of the "harmonious-equipotential system," which will be discussed in another chapter.

† Morgan, *op. cit.*, p. 136.

‡ *Op. cit.*, p. xii.

in simple terms, the inadequacy of some of the working hypotheses that have been our guides."

The facts of development and the observations which are due to the labours of the experimental embryologists present us with a picture wholly different from that afforded by a contemplation of the processes of inanimate bodies and it is the contemplation of this wide and unbridgable difference which seems to be leading those or many of those whose work is chiefly of an embryological character to the conclusion that some kind of force other than that recognised by chemists and physicists must have its existence in the living cell, a force which is able to direct it to its appointed term of development and even, as we have seen, to lead it there in spite of difficulties which it could never have been supposed a few years ago by any scientific man would have been placed in its way.

CHAPTER VIII

BIOGENESIS AND ABIOGENESIS

History of the Controversy—Dr Bastian's Views—Where did Living Matter come from—The Catholic Position.

THOSE who have followed the facts laid down in the last chapters will now be able to ascertain the foundation on which are constructed the four axioms mentioned in Chapter IV. :—*Omne vivum ex vivo, omnis cellula ex cellula, omnis nucleus e nucleo, omne chromosoma e chromosomate.* Something, however, still remains to be said respecting the first axiom, for after centuries of discussion the question of biogenesis or abiogenesis still seems unsettled to some.

Ambiogenesis

Looking at things as we see them it is not wonderful that men should have believed, from the time of Aristotle onwards down to the seventeenth centry, that living things could come directly from non-living things, that reptiles and worms were bred from the mud of rivers and that decaying flesh produced maggots. Harvey first proclaimed the contrary doctrine, and Redi, an Italian physician,

showed in 1698 * that maggots found in putrid flesh had not arisen from the meat but from the eggs of flies deposited thereon, and moreover demonstrated the fact that if the meat was kept covered with gauze no maggots appeared in it. And as a result of this and of other observations the idea of spontaneous generation was put aside for a time, indeed until the microscope began to reveal the surprising number and variety of small living objects which had previously been hidden from men's eyes. The discussion continued at intervals during the eighteenth century and it is curious to note that two of the most active antagonists were both Catholic priests,† Needham (1713-1781) who supported the theory of spontaneous generation, and Spallanzani‡ **Spallanzani** who opposed it. It was Spallanzani who first performed the experiment of boiling infusions for a sufficient time in hermetically sealed vessels, after which treatment, as he showed, no life was developed in them.

After this demonstration the theory of spon-

* Francisci Redi Patritii Bretini, *Experimenta Circa Generationem Insectorum.*

† Turberville Needham, the first Catholic ecclesiastic to be elected F.R.S. (in 1746), was born 1731 and died 1787. Driesch incorrectly describes him as a Jesuit.

‡ Lazaro Spallanzani (1729-1799), also incorrectly described by Driesch as a Jesuit, was, like Needham, a secular priest. A brief account of these two men will be found in my book, "Science and Morals and other Essays," Burns and Oates.

taneous generation was once more consigned to oblivion, or at least to comparative oblivion, for it has always possessed certain adherents.

Pouchet

Amongst these the most important was the elder Pouchet who in 1858 declared that he had seen the spontaneous production of infusoria in a sterilised fluid which had been exposed only to air also deprived of all germs. The discussion on this subject became so active that the French Academy of Sciences in 1860 offered a prize for the solution of the matter.

Pasteur

It was then that Pasteur* came upon the scene and made the classical experiments which will always be associated with his name. First of all he showed, as Spallanzani had done before him, that infusions in which life would have appeared if they had not been sterilised, or if, after sterilisation, they had been left exposed to the air, would, if boiled for a sufficiently long time, and retained in closed vessels, remain permanently without any signs of life. Then it was argued that this was because the fluid was deprived of fresh air. To this Pasteur retorted by the further experiment of filtering the air which was admitted to the sterilised fluid through a wad of cotton-wool. He even showed that if the flask in which the sterilised

* 1822-1895. For an account of his life see "Twelve Catholic Men of Science," C.T.S., 1914.

fluid was placed had a long neck bent into a zig-zag shape the contents remained untainted by life. The explanation of all these things is very simple, now that we know it. The air all around us is full of minute organisms, such as bacteria, which are capable of growing and multiplying with enormous rapidity in various infusions, such, for example, as beef-tea, and, by their growth, of causing the putrefaction of the fluid in question. Hence in all such fluids which have been exposed to the air there are these small organisms and it is only a question of time as to when the fluid will "go bad" as we commonly put it. Let, however, such a fluid be boiled for long enough and all the organisms which it contains will have been killed and the fluid rendered temporarily sterile. Now if it is again exposed to the air it will again accumulate bacteria and again commence to decompose. Let us suppose, however, that when the process of boiling has gone on for long enough and the fluid is quite sterile, the neck of the flask in which it has been boiling is hermetically sealed up. No further bacteria can obtain admission and the contents will remain "good" as long as the seal of the neck remains perfect. It is on this experiment that the "canning" trade has been built up and every glass jar of soup or of calves'-foot jelly

The "canning" trade

which we look at in a shop window is a standing proof of the truth of the facts which Pasteur proclaimed. As to the other two experiments, in the one case the bacteria are filtered out of the air mechanically by the wad of cotton-wool. The other is also a case of mechanical separation, for the tubular neck of the vessel being narrow and the bends in it frequent the bacteria become deposited on the sides of the tube before reaching the fluid contained within the flask. As a result of these experiments the view that all living matter is derived from living matter is now almost universally held, though, of course, what Pasteur really proved was, not that living matter never arises from non-living matter, but that by observing certain laws and taking the necessary precautions certain substances which would otherwise become invaded by living things which would seize upon them for their food, would be kept intact from them. But as it was the appearance, apparently spontaneously, of life in such substances which had formed the foundation of the theory of spontaneous generation it has often, though inaccurately, been assumed that Pasteur proved that spontaneous generation does not take place.

Since his time scientific opinion is unanimous that there is no proof that spontaneous genera-

tion takes place, all experiments to demonstrate it having failed. A few opinions may now be quoted.

Tyndall * said: "If you ask me whether there exists the least evidence to prove that any form of life can be developed out of matter without demonstrable antecedent life, my reply is . . . men of science frankly admit their inability to point to any satisfactory experimental proof that life can be developed save from demonstrable antecedent life." And that he remained of this opinion is shown by a statement four years later: † "I affirm that no shred of trustworthy experimental testimony exists to prove that life in our day has ever appeared independently of antecedent life." **Biogenesis**

Huxley, though he thought that spontaneous generation was "a necessary corollary from Darwin's views if legitimately carried out,"‡ yet admitted that in the controversy between biogenesists and abiogenesists the former were "victorious all along the line."§ Virchow, the author of the *Cellular Pathology*, one of the greatest men of science of the last century, said in 1887: ‖ "Never has a living being, or even a living element—let us say, a living cell **Virchow**

* "Belfast Address," 1874. † *Nineteenth Century*, 1878.

‡ Letter to Charles Kingsley, *Life and Letters*, i., 352.

§ *Critiques and Addresses*, Presidential Address to British Association.

‖ In an address delivered at Wiesbaden.

—been found, of which it could be predicated that it was the first of its species. Nor have any fossil remains ever been found of which it could ever be likely that it belonged to a being the first of its kind, or produced by spontaneous generation."

Three further authorities from many who offer similar testimony will serve to close this catena of quotations. These three shall be a biologist, a chemist and a bio-chemist. Hertwig in his magistral work* says: "In the existing condition of Science there is little hope that any worker will be able to produce the simplest manifestation of life in any artificial way from non-living matter. He has certainly no more chance of success in his endeavours than Wagner, in Goethe's 'Faust,' had of brewing a Homunculus in his retort."

Tilden Sir William Tilden, F.R.S., recognised as one of the first authorities in organic chemistry, says: † "Chemical synthesis has accomplished some wonderful things by well-known laboratory methods. These methods involve very commonly the use of high temperatures, caustic alkalis, strong acids, and solvents such as alcohol, ether or acetone, which at any rate in a concentrated form, never appear among

* *Allegem, Biologie*, 2te Aufl., s. 263.

† *Chemical Discovery and Invention in the Twentieth Century*, Routledge, 1916.

the constituents of either plant or animal. In fact, the processes of the laboratory have not the remotest resemblance to those which must be assumed to go on in living tissue. The chemist can take carbon and hydrogen and by the aid of a high temperature can make them to combine to produce ethylene. From ethylene he can build up tartaric acid by a series of steps which, however, require the use of chlorine or bromine. The grape vine also manufactures tartaric acid, but it uses neither a high temperature nor a halogen" (*i.e.*, an element of the group to which the two above-named bodies belong). Again, after discussing Moore's observations on formaldehyde: "We may even go farther and suppose that, by a series of changes the nature of which cannot now even be conjectured, a complex colloidal protein was actually formed. We may in the present state of knowledge safely inquire—What then? No chemist will be induced to believe that a pulpy mass of one or more aminoacids, no matter how complex or how associated with saline electrolytes, will cease to exhibit the characters which belong to chemical compounds in general, and acquire of its 'own mere motion' the power of utilising and controlling energy supplied from external sources in such a way as to give rise to the

cycle of events exhibited in every particle of living substance from the amoeba onwards." "Protoplasm cannot be thought of merely as a solution of mixed colloids and saline electrolytes. It must consist of aggregates or clusters of molecules of various dimensions and possessing a consistency which no solution could show, inasmuch as a solution would possess viscosity and cohesion equal in every direction. The amoeba if merely a drop of colloid solution would, like a drop of any jelly, gradually, melt away into the surrounding water by the operation of ordinary liquid diffusion. The amoeba has extensibility and retractility, and therefore cannot be an ordinary solution." "Those who accept the purely materialistic doctrine as to the origin of life have before them the necessity of establishing a vast number of facts before such doctrine can be made generally acceptable to the scientific world. The progress which has been made in the desired direction is far from being as yet a justification for the pronouncements which have within the last few years found their way into print and which have too much the air of being uttered *ex cathedra*" (pp. 463-8).

Moore Professor B. Moore, whose distinction as a bio-chemist renders him a peculiarly valuable witness on this point, shall conclude the list.

He says: * "The mode of production of living matter is characteristic, and cannot be brought about by the action solely of inorganic forms of energy. Living matter is produced only by the action of other living matter upon the materials and forms of energy of the non-living world. In the process the matter involved is built up into substances of great chemical complexity, and it has been supposed that this is the essential portion of the process of production of a living structure; but it must be noted that even this very production of complexity of structure from simple inorganic bodies at the expense of the energy of the solar rays take place and can only take place in a living structure itself. The very building up of the machine or transformer in which the manifestations of biotic energy are subsequently to take place is then a cogent argument that here we are dealing with a type of energy which is not met with elsewhere. For nowhere else in Nature does a similar process appear to that of the production of living structure, and by no combination or application of the forms of energy apart from life can it be repeated or simulated."

It has seemed advisable to give this somewhat lengthy list of quotations in order to show

* *Recent Advances in Physiology and Bio-Chemistry.*

that, though the possibility of spontaneous generation occurring cannot be excluded, there is at least an overwhelming belief that there is no evidence for its occurrence.

Bastian

The two latest attempts to dispute this conclusion must not be passed over without mention. The first is that of the so-called radiobes produced by the late J. B. Burke * by the action of radium upon beef bouillon. We need not delay over these appearances since they have been shown to be chemical in their character and to have nothing whatever to do with life or its beginings.

Burke

Dr Charlton Bastian was one of Pasteur's antagonists during the time when the question of biogenesis or abiogenesis was really a burning one, and, even after the publication and general acceptance of Pasteur's conclusions, he courageously returned to the charge in a book † in which he maintained that Pasteur gained the victory by the aid of "illogical methods," a statement which was not very complimentary to the rest of the scientific world which had been quite imposed upon by these same methods. In this book he once more declared that he had been able to produce living from non-living materials.

* *The Origin of Life*, 1906.
† *The Evolution of Life*, 1907.

On this it may be remarked that if this were true the whole edifice which the modern science of bacteriology has built up comes to the ground and that it is a little remarkable that no one of the thousand workers at that subject have ever come in contact with any of the discoveries which Dr Bastian thought that he had made.

Perhaps the reason for this may be found in a passage in which Dr Bastian * says that: "Bacteriologists, as a result of repeated processes of heating at brief intervals and often at high temperatures for the special purpose of bringing about complete sterilisation, not only kill all pre-existing micro-organisms, but, as I maintain, destroy also any potential germinality of the media themselves. These media, after having been treated as above indicated, will nourish and favour the multiplication of living bacteria with which they are inoculated, but they will never engender them. They behave, in fact, exactly like a boiled ammonium tartrate solution—this also does not engender, but will freely nourish bacteria. As a result of habitually dealing with media thus treated (though they know that, with the exception of the spores of bacilli, all the microbes in their media may be destroyed by being boiled once only, for five minutes or less , bacteriologists

* P. 312.

have come to the conclusion that bacteria never arise *de novo*." The repeated boilings and the high temperatures employed by bacteriologists are made use of for the very purpose of sterilising the media, and that the operation is a successful one seems to be proved by the facts admitted by Dr Bastian, namely that (i.) no new life appears without inoculation and (ii.) that after inoculation the fluid can support the introduced life. It has not been injured as a pabulum though all pre-existing life has been destroyed in it. Dr Bastian claims that besides the power of maintaing life there is also a power of engendering it which is destroyed by those measures which bacteriologists think necessary for the production of complete sterilisation. All that one can say is that if the power of engendering is not due to the presence of bacteria unkilled on account of insufficient sterilisation it is a power which has not been recognised by any other worker.

Where did living matter come from?

Suppose we grant that living matter has always come from living matter, which is indeed the scientific creed of the day, where did the first living matter come from? This world was once so hot that no living thing could exist upon it. It cooled down and a time arrived when life could exist. Where did it come from? Some space must be devoted to

the consideration of this very important and much discussed question. It has been suggested that living matter might have been brought to this world from some other by means of a meteorite. This was the suggestion put forward, amongst others, by the late Lord Kelvin, one of the most distinguished physicists the world has ever seen. He declared that "dead matter cannot become living without coming under the influence of matter previously living. This seems to me as sure a teaching of science as the law of gravitation."

Hence * after alluding to the collisions between heavenly bodies and the projection through space of some of their fragments he says: "Because we all confidently believe that there are at present, and have been from time immemorial many worlds of life besides our own,† we must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about in space. If at the present instant no life existed upon this earth, one such stone falling upon it might, by what we blindly call *natural* causes, lead to its being covered with vegetation." So distinguished a physicist as Lord Kelvin cannot have

* Address to British Association, 1871.

† It ought to be added that this confident belief on the part of Lord Kelvin was not and is not shared by all men of science. See Wallace's *Man's Place in the Universe* (Chapman & Hall, 1904) for a discussion of this question.

failed to consider the difficulty raised by the intense heat engendered in these fragments when they enter our atmosphere, a phenomenon which we are familiar with in the shape of "shooting stars." But it has been suggested that the germs of life might have lain safely concealed in deep cracks in the meteorites and so on. A variant of this view is found in the

Arrhenius

theory of Arrhenius put forward before the existence of ultra-microscopic bacteria was known, as it is to-day, and perhaps strengthened by that discovery. He postulated the existence of vast quantities of such bodies in space driven towards the earth by the action of the waves of light, just as these impel the vanes of Crookes' radiometer which we may see spinning in a vacuum bulb in the windows of instrument makers any sunny day. If these germs were small enough they might attain a great velocity; in fact Arrhenius calculated that they might travel from Mars in twenty days and from ours to the nearest solar system—or of course *vice versa*—in about nine thousand years.

From our point of view this discussion, though interesting, is purely academic. To tell us that the palm trees on a coral island sprang from nuts washed up from some distant land explains the palm trees on that particular

island but does not explain palm trees in general. And the possible existence of living germs in space does not explain the origin of life. We may, therefore, pass to other suggestions, prefacing them by a statement of Naegeli, a most distinguished botanist: "If in the physical world all things stand in causal connection with one another, if all phenomena proceed along natural paths, then organisms which build themselves up from and finally disintegrate into the substances of which inorganic nature consists, must have originated primitively from inorganic compounds. To deny spontaneous generation is to proclaim a miracle." With this statement we can only quarrel on one point and that is the ill-chosen word *miracle*. In the sense of *miraculum*—a thing to be wondered at—the word is all right, but philosophically it is all wrong. The scholastic definition of a miracle is *Opus sensibile, divinitus factum, insolitum, supernaturale*—sensible, effected divinely, unusual, supernatural. And St Thomas says that "those effects are rightly to be termed miracles which are wrought by divine power apart from the order usually observed in nature." Or again: "Those effects are rightly to be termed miracles which are wrought by divine power apart from the order usually observed in nature." If

A Miracle

spontaneous generation is going on all around us, and there is nothing to prove that it is not, it is not a miracle in any proper sense of the word, but a part of the operations of nature. If it is not going on around us, but life was once infused into inorganic nature and has gone on propagating itself ever since then, again, it was not a miracle in any proper sense of the word but a fore-ordained part of the general scheme of life progress. It is certainly true that if we deny spontaneous generation we must —since there is no other alternative—affirm the action of a Creator, and that seems to be the reason for the ardent affection shown to the first-named view by some of its supporters. But the reverse is by no means true as some would seem to imagine, for the acceptance of spontaneous generation in no way does away with the necessity for a Creator, as will shortly be shown.

Some, like Sir E. Schaefer in his Presidential Address to the British Association in 1912, would have us believe that the promise of life is to be found in those very interesting and complicated bodies the colloids (*i.e*, glue-like substances), which are undoubtedly the underlying fabric of many of the processes of life. But the words were hardly out of his mouth when the chemists arose in a body to declare

that they at any rate saw no signs that the problem of the origin of life was on the point of being solved through this branch of their science. Some stress has been laid by Bach on the fact that a substance known as formaldehyde, and regarded by botanists as the first step in the synthesis of sugar in green plants, is formed artificially when, in the presence of sunlight, carbon dioxide is passed through a solution of a salt of uranium. The observation is no doubt one of considerable interest, yet it does not carry us very far. In fact Bateson scoffingly says of it in his Presidential Address to the British Association in 1914, that he is reminded by it of nothing so much as of Harry Lauder, in the character of a schoolboy, "pulling his treasures from his pocket: 'That's a wassher — for makkin' motor-cars.'!" Formaldehyde

As there are no scientific facts to help them and as the problem is one clamant of explanation, various purely hypothetical explanations have been given of which some mention must now be made. A half-hearted suggestion by Osborne * that there might possibly be an unknown chemical element which might be called Bion may be passed over, since it is not seriously pressed; there is not the remotest evi- Bion

* *The Origin and Evolution of Life.* Bell, London, 1919.

dence for it; and, if it did exist, it would have to be far more wonderful than radium is, were it to explain all the processes for which it would be resopnsible. Let us dismiss Bion, and pass to another postulated possibility, Protobion, as suggested by Gregory.* In his opinion, "the problem of the origin of life is that of the formation of quantities of carbonaceous jelly under such conditions that it would have continued to increase until the masses mechanically subdivided, and the separate parts would inherit the power to grow and subdivide in turn. The problem is that of the formation of a self-generating, reproductive, carbonaceous jelly, of such a nature that it served as the beginning of the whole of the organic evolution that followed." No doubt; but supposing such a jelly to be sufficient—which it could not be—to account for the process, how did it arise? In the warm, muddy oozes near some prehistoric sea he thinks that "a complex, vaseline-like jelly may have been deposited from the carbon compounds in the atmosphere, and have been combined with various compounds of nitrogen, chlorine and phosphorus." And so on, until the "primordial jelly was vitalised by the action of one of the reagents known as catalysers." No doubt catalysers are very re-

Carbonaceous jelly

* *The Making of the Earth.* Home Univ. Library, p. 229.

markable things, as we shall yet learn in these pages, but let us pause for a moment and survey the edifice of assumption the erection of which we have been watching. First of all we have to assume the formation of the vaseline with its powers of division; which perhaps we may accept without any very great hesitation, though there is no sort of evidence for the division part of the theory. But suppose that it did mechanically subdivide, where did it suddenly become endowed with heritable powers—powers mysterious beyond most of those with which we are confronted in nature? This is an assumption which it is really impossible to swallow, except on the theory that this was the method adopted by the Creator—the great First Cause—for the origination of life. The fact is that—as other and greater persons have declared, such as Wallace—when we arrive at the origin of life, we arrive at a point so momentous that we must seek for its explanation outside the ordinary processes of nature. Let us be clear on this matter as to which there has been quite extraordinary misunderstanding. Our view as to Creation is not the crude view which some attribute to us in which—as they put it—the Creator is perpetually "interfering" —correcting as it were or revising His own work. They might reasonably condemn—as

Creation

they do—such a theory as "anthropomorphic," but in condemning it they are setting up a man of straw. That is not our view. Our view is that the idea of the earth and of living things existed from all eternity in the mind of its Creator; that things came to be as and when they were intended to be; that just as the clock strikes twelve when the clockmaker intended it to, though it can scarcely be said that he made it strike at the moment at which its chime was actually heard, so at the time when life was to appear, it did appear and appeared by means of whatever mechanism it was intended that it should appear by.

The reply of some will be that an assumption is being made here. Is it as unlikely an assumption—if for a moment we pass the word—as the vaseline-jelly assumption *minus* any further cause? I confess that on the most rationalistic grounds I do not think so, but there is more to be said, and without discussing the question of the existence of God which is dealt with in many works of much greater erudition than this and cannot be detailed here. But we may just point attention to St Thomas' "*Quinque viae*," or five roads to the proof in question. They are all of them important and as we think unanswerable, but the fifth is highly germane to our purpose and we may

Quinque viæ

quote it in full.* "The *fifth* way is taken from the government of things. For we see that some things which lack knowledge, namely, natural bodies, operate for an end. This appears from the fact that they always or often operate in the same way so that they may do the best. Hence it is clear that they reach their end, not by chance but by design. But beings that lack of knowledge do not make towards an end unless directed by some cognoscitive and intelligent being, as the arrow by the archer. Therefore there is some intelligence by whom all natural things are directed towards their end; and this we call God."

There is just one point of interest before we leave this matter. The entire living world depends upon the energy derived from the sun for the building up of those organic colloids of which living structures are made up, and the energy-transformer is the green-celled plant by virtue of the colloid *chlorophyll* which it contains. Those non-green-celled plants such as fungi and bacteria are dependent as parasites or saprophytes on green-celled things, and so are animals, either directly as herbivores or indirectly as carnivores.

* Translation of Fr. V. M'Nab, O.P., as given in his most admirable little penny pamphlet entitled *Aquinas*, and published by the Catholic Truth Society.

Yet is seems unlikely that the earliest plants can have been chlorophyllaceous, since chlorophyll connotes a considerable advance in complexity. In this connection it is interesting to note that we have knowledge of bacteria which can feed directly on inorganic substances such as *Nitrosomonas*, a prototrophic bacterium which as Osborne * tells us, "for combustion . . . takes in oxygen directly through the intermediate action of iron, phosphorus or manganese, each of the single cells being a powerful little chemical laboratory which contains oxidising catalysers, the activity of which is accelerated by the presence of iron and manganese. Still, in the primordial stage, *Nitrosomonas* lives on ammonium sulphate, taking its energy (food) from the nitrogen of ammonium and forming nitrates. Living symbiotically with it is *Nitrobacter*, which takes its energy (food) from the nitrates formed by *Nitrosomonas*, oxidising them into nitrites. Thus, these two species illustrate in its simplest form our law of the *interaction of an organism* (*Nitrobacter*) *with its life environment* (*Nitrosomonas*)."

Nitrosomonas and nitrobacter

It must be confessed that this very interesting observation does not in any way help us to find a materialistic explanation of life, nor

* *Op. cit.*, p. 82.

even an explanation of the way in which chlorophyll came into being, but it does seem to expose some of the lowest rungs of the ladder of life once that elusive but potent factor had come into operation.

Faced with the difficulty of accounting for the origin of life and unable to assert that it is actually originating all round us to-day, some men of science have claimed—as we have already seen—that though spontaneous generation does not take place or cannot be proved to take place nowadays, yet it must have taken place at some former period, when conditions on the earth were far different from what they now are; "at a remote period in the past, when the temperature of the surface of the earth was much higher than at present, and other physical conditions were unlike those we know, inorganic matter, through successive complications, gave origin to organic matter," as Herbert Spencer put it.*

"Successive complications"

Huxley † thought that if it were given to him "to look beyond the abyss of geologically recorded time" he might "expect to be a witness of the evolution of living protoplasm from not-living matter."

Huxley

On a careful consideration of all the state-

* *Nineteenth Century*, May, 1886.
† *Critiques and Addresses*, p. 239.

ments reviewed in the pages immediately preceding it may be remarked :—

1. It is quite certain that no person has ever seen living matter produced from not-living matter now or at any previous time.

2. It is equally certain that we have no facts on which to base the theory that it was spontaneously produced at some former period.

3. Nor have we the slightest suggestion from those who put forward the theory as to how the transformation may have taken place or under what conditions, nor are we told why it is impossible to reproduce those conditions in the chemist's laboratory. We are treated to a good many nebulous phrases, like Spencer's truly delightful and luminous explanation of "successive complications," but of solid bed-rock fact we get nothing whatsoever.

4. Finally, that as science deals and can only deal with ascertained facts, theories of this kind must be taken for what they are, namely, "pious opinions," and estimated at the value which they therefore possess.

Weismann

Weismann, the distinguished biologist, declares,* "that spontaneous generation, in spite of all vain efforts to demonstrate it, remains for me a logical necessity."

Why a logical necessity? Is it because the

* *Essays*, Poulton's Trans., p. 34.

only alternative is a return to the view that life was introduced into this world by the action of a Creator? It is generally—perhaps incorrectly—assumed, that by spontaneous generation (in writings of the class from which we have been quoting) is meant spontaneous generation by the powers of nature alone and with no reference to a Creative act, which, indeed, it can scarcely be doubted, is denied by some, perhaps many, of these writers. A lamentable want of clearness in writing and, at times apparently, in thought makes one uncertain as to their real views on this matter. At any rate, let a biologist answer those who would dispense with a Creator. Reinke * states it as his opinion, and we may fully concur with him, that "If we agree that living matter has at some time come from inorganic substances then, in my opinion, the Creation hypothesis is the only one which meets the necessities of Logic and of Causality and therewith answers to the needs of a prudent seeker after nature."

There are two further points which must be touched upon before this matter is concluded.

May living come from not-living matter?

In the first place one must be quite clear of this fact that though the genesis of living from not-living matter has never yet been demonstrated it is not, therefore, impossible that it

* *Einleitung in die Theoretische Biologie*, s. 559.

may some day fall to the lot of some fortunate investigator to announce such a discovery and to have his discovery recognised by a scientific jury. And if this were to be the case we may be quite sure that there would be hosts of persons prepared once more to announce the annihilation of all religion by the last great scientific discovery.

Aquinas and Avicenna

Such persons would be forgetful if not ignorant of the fact that the theory of spontaneous generation was held by many, perhaps by all the Fathers of the Church, and that St Thomas Aquinas himself when rebuking Avicenna for teaching spontaneous generation did so because Avicenna held the thesis that it was by the power of matter alone that life arose, whereas, as St Thomas says, if matter does produce life it is because the Creator has given it the power to do so *; in fact, the age-long controversy which we have been occupied with in the preceding pages.

If we consider the matter, such a transition from non-living to living matter at some period is far the most likely thing to have occurred. What we claim is that, if it occurred, it did so at the will of the Creator and by virtue of the powers which He gave to it, nor do we deny that it is possible that that power is still in-

* *Summa Theol.* 1. p. q. 71 art. 1, ad 1 um.

herent in non-living matter and may even be continually manifested, though we are unable to recognise the fact. "If," says Fr. Sharpe,* "against all probability, life could be shown to be spontaneously generated from matter, this would merely mean that the sentient or vegetative soul [which one may also speak of as the vital principle or under any other term which connotes the existence of an extra-physical agency in living matter] is a resultant from certain chemical combinations, and not, as has been supposed, the direct work of the Creator. But there is no more inherent impossibility in holding that animal life is brought into being by a certain combination of chemical substances than in the converse belief, which is incontestable, that it is brought to an end by the dissolution, natural or artificial, of that combination. If we can destroy an animal's soul, as we certainly can, there is no *a priori* reason why we should not be able to make one."

Whilst, however, we allow all this, we must admit, with all who have studied the subject, that no approach has been made to any synthesis at all approaching that which would constitute living matter, and that those syntheses of organic compounds which have been arrived

* *The Principles of Christianity*, 1906, p. 56.

at, and to some of which allusion has been made, do not afford any help in the direction in question as some have thought that they do. This is the second and final point, and it may be clinched by quotations from two very distinguished chemists.

Roscoe

Sir Henry Roscoe* says: "It is true that there are those who profess to foresee that the day will arise when the chemist, by a succession of constructive efforts may pass beyond albumen, and gather the elements of lifeless matter into a living structure. Whatever may be said of this from other standpoints, the chemist can only say that at present no such problem lies within his province. Protoplasm, with which the simplest manifestations of life are associated, is not a compound, but a structure built up of compounds. The chemist may successfully synthesise any of its component compounds, but he has no more reason to look forward to the synthetic production of the structure than to imagine that the synthesis of gallic acid leads to the artificial production of gallnuts."

And a more recent utterance of the same kind has been made by Professor B. Moore† when speaking of "the products formed interstiti-

* Presidential Address, Brit. Ass., 1887.
† *Recent Advances, etc.*, p. 10.

ally within the cell. Most of these," he says, "are so complex that they have not yet been synthesised by the organic chemist; but even of those that have been synthesised, it may be remarked that all proof is wanting that the syntheses have been carried out in identically the same fashion and by the employment of the same forms of energy in the case of the cell as in the chemist's laboratory. The conditions in the cell are widely different, and at the temperature of the cell and with such chemical materials as are at hand in the cell no such organic syntheses have been artificially carried out by the forms of energy extraneous to living tissue."

Lest any false deductions should be drawn from an omission to mention them some reference should perhaps be made to Le Duc's artificial plants* though no one now regards these things as anything but a pretty and interesting experiment without any bearing on the question of life. Le Duc made seed-grains from 1/25 to 1/12 of an inch in diameter, composed of two parts of sugar and one of sulphate of copper. Placed in water in which was 1/4 per cent. of gelatine, 1 to 10 per cent. of common salt and 2 to 4 per cent. Ferrocyanide of Potassium,

Le Duc

* As described and figured in his work, *The Mechanism of Life*, London, Rebman, 1911.

certain reactions take place whereby the grain grows and develops into a plant-like form. Sir William Tilden says: "There is just as much resemblance" (between these objects and plants) "as is to be found between the forms of fossil plants in the more ancient rocks and the foliaceous tracery produced by frost on the pavements in winter."*

* *Op cit.*, p. 465.

CHAPTER IX

ADAPTATIONS

Purposive Actions in Living Things.

IN a previous chapter some mention has been made of that useful word adaptations, so frequently employed with the idea that it affords a complete explanation, in itself, of the phenomena with which it is connected. "Adaptations"

It is astonishing how many persons can be satisfied by a mere phrase and hundreds go happy away when told that Nature does so and so or provides for such and such a condition of affairs without appearing to be in any way concerned as to who or what Nature is or how it performs the wondrous works with which it is credited.

It is the same with that blessed word "inherent" which is also constantly used as if it were an explanation instead of a mere naming of a fact. That certain characteristics are inherent, say in a bull, is no doubt perfectly true, but to tell us that a bull is quarrelsome at times "Inherence"

because that quality is inherent in bulls is certainly no explanation of how bulls came to have the quality in question.

If it be retorted that the upholders of a vital principle or force in Nature are also guilty of a mere verbal explanation, such a retort on superficial examination would appear to have some force. But there is really no resemblance between the two conditions, as will be shown in the concluding chapter of this book.

To return to the question of adaptations; when your hardened opponent of all esoteric explanations is sore gravelled to account for a fact "adaptation" is the steed on which he usually declares to win. Thus Weismann, endeavouring to account for behaviour on the part of a tubularia, which, to say the least of it, hardly seems to harmonise with the theories of that distinguished biologist,* says: "This also appears to us to be adaptive, and does not surprise us, since we have long been accustomed to recognise that what is adapted to an end will realise this if it be possible at all," and again, in a passage in which we have Nature brought in in the manner above alluded to: "It was, so to speak, not worth Nature's while to make such adaptations." It must be quite obvious to any person who thinks that

* *The Evolution Theory*, ii., 9.

such an explanation is really no explanation at all. A mowing-machine is no doubt adapted for keeping a lawn smooth and a pump for raising water from a well, but both of these are so adapted because they have been made for that pupose and no other. The term adaptation is only utilisable in connection with a telic explanation of living things, and it is just that telic explanation which is so unpalatable to the mechanist school. Yet it is difficult to see how such an explanation can be avoided by any one who really studies the behaviour of living things.

Adaptation of machines

Our own behaviour and the behaviour of the animals and birds around us would seem to point clearly enough to purposive actions, and this is a fact which is tacitly at least admitted even by those who believe most strongly in mechanist views.

If any machine habitually repeats the same action and repeats that action in a precisely similar manner on every occasion, no one could have much difficulty in coming to the conclusion that it was for the purpose of performing that action that it was constructed. Moreover, if it performs no action but the one, it may reasonably be assumed that that action is automatically performed and no question as to the sentient nature of the machine will arise. On

the other hand, whilst we can conceive—though with some difficulty—the idea of a machine which was capable of executing a wide and various range of movements, differing from one another in character and practically independent of one another, it is hard to think of a machine which could execute a wide range of movements and always and on every occasion in a new way. Such a machine is quite inconceivable. Yet even the most strenuous supporters of the mechanical school are constrained to admit that the living thing constantly varies its method of meeting the various conditions with which it is confronted. "A living being," says M. Le Dantec,* "is not like an industrial machine manufactured with the design of accomplishing a certain kind of work and able to do no other. A locomotive can exercise only the locomotive's function. On the contrary, a dog, a duck, a serpent, are able to manifest in a thousand different ways *according to circumstances* their specific activity as dog or duck or serpent. Now, circumstances so vary around any given animal and the animal itself changes so quickly that we may say without exaggeration *an animal never does twice the same thing in the whole course of its existence.*"

The argument in the book from which this

* *Op. cit.*, p. 67.

quotation has been taken is that the actions of living things are the result of tactisms and that these are due to changes in the chemical composition or reactions of the colloids of which the body is made up. Of what nature, one may fairly ask, are those chemical compounds which never react twice in the same way?

Purposive actions

Even amongst the smallest and simplest forms of animal life it is possible to come across actions which are undoubtedly purposive. One or two examples of these may now be cited.

Cienkowski* has described a little naked unicellular organism, very much like the Amoeba which formed the subject of our study in an earlier chapter. Like the Amoeba it lives in water and like it too it moves by a kind of crawling motion due to the protrusion of processes from its own body up to which the remainder of the body is drawn. Living in the water it is, of course, surrounded by a great variety of water-plants small and large, any of which, one might have supposed, would have sufficed for its food. Such, however, is not the case. Of all the algae or water-vegetables by which it is surrounded, it in-

* The instances now about to be narrated have been detailed by Pauly in his book, *Darwinismus und Lamarckismus*, München, 1905, s. 147.

variably seeks out one and one only, namely Spirogyra and makes its meal off that.

Obviously it finds that the Spirogyra suits it best or, as we should put it, it prefers Spirogyra to any other kind of food, just as we too have our preferences in the same matter.

Colpodella

The same observer in relating the habits of another unicellular organism, called Colpodella pugnax, tells us that it lives solely on an alga called Chlamydomonas, whose chlorophyll, or green colouring substance, it sucks. Cienkowski says that the behaviour of this lowly organism in hunting after and obtaining its favourite nourishment is so remarkable that one is led to believe that one sees the operations of conscious life in it.

It is possible that some might argue that the attraction between these minute organisms and their food was entirely of a chemical character, but if so the argument must clearly be extended to all classes of living things and their food, and that would lead us on to conclusions, when we consider our own habits in respect to food, which few would be found to accept.

Foraminifera

Amongst the Foraminifera, however, we can find instances which cannot be accounted for in this way.

These also are unicellular and microscopic

and have the habit of encasing themselves in tiny shells, perforated by one or more holes—whence their name—through which are protruded the pseudopodia or protoplasmic processes by which they take hold of their prey or move about.

Tiny as they are, their bodies make up vast rocks, for most of the chalk consists of their remains and much of the oolite which forms a great band across England in the district of the Cotswolds is also constructed from the remains of these little creatures.

Enlarged models of the shells of the Foraminifera may be seen in most zoological and geological museums and very beautiful objects they are. It is in the selection of the appropriate kind of substance for the construction of their shells, or "tests" as they are called, that we find our first example of the purposive actions of these little things.

Carpenter * says on this point: "The tests which they construct, when highly magnified, bear comparison with the most skilful masonry of man. From the same sandy bottom one species picks up the coarsest quartz grains, unites them together with a ferruginous cement, and thus constructs a flask-shaped test, having a short neck and a single large orifice; another

* Art. "Foraminifera," *Encyclopædia Britannica.*

picks up the finer grains and puts them together with the same cement into perfectly spherical tests of the most extraordinary finish, perforated with numerous small pores disposed at pretty regular intervals. Another species selects the minutest sand-grains and the terminal portions of sponge-spicules, and works them up together—apparently with no cement at all, but by the mere laying of the spicules—into perfect white spheres like homœopathic globules, each showing a single-fissured orifice. And another which makes a straight, many-chambered test, the conical mouth of each chamber projecting into the cavity of the next, while forming the walls of its chambers of ordinary sand grains rather loosely held together, shapes the conical mouths of the chambers by firmly cementing together the quartz grains which border it."

Well may the writer just quoted add the remark: "There is nothing more wonderful in nature than the building up of these elaborate and symmetrical structures by mere jelly-specks, presenting no traces whatever of that definite organisation which we are accustomed to regard as necessary to the manifestations of conscious life."

In this variety of construction and in this choice of materials it is hard not to see purpose.

However, a further example of the purposive actions of these minute forms may be given before we leave them. There is a foraminifer named Arcella which makes for itself a round concavo-convex test. On the concave side there is a single central round opening through which it is able to protrude its pseudopodia. Arcella

One may colloquially speak of this surface as its front and the convex aspect as its back. Now sometimes it will occur that Arcella will tumble over on to its convex back and in that position one would suppose that it would be as powerless and even more helpless than the beetle which one sees feebly moving its legs and wondering apparently how it is ever going to get upon them again.

Arcella has its own method of achieving this task. It sets to work and by means of some mechanism of which we know nothing, it produces gas-bubbles in its interior.

These are arranged in one of two ways. In some cases they form at one side of the body only. The result is that that side is floated upwards and the little creature comes to stand on its edge. From that position it is easy, by the aid of its pseudopodia, for it to resume its normal position with the pseudopodia downwards.

In other cases the gas-bubbles, instead of being confined to one part of the body, are generally disseminated throughout it. The consequence of this is that the entire organism becomes sufficiently light to float to the top of the water in which it is immersed. There it is able to assume the position which it desires.

Such a purposive action as this is wholly different from the actions of chemical substances or of those which we study in the physical laboratory.

Forces of this latter kind look backward, not forward, for their explanation. They are the result of what has been and the end of the series of occurrences is an equilibrium.

Let us take an example. Suppose we add oil of vitriol—sulphuric acid—to a piece of carbonate of lime. There will be profuse effervescence, due to the breaking up of the union between the carbonic acid and the lime and the giving-off of the former in the shape of gas. After a time this will cease and all the carbonic acid gas having been got rid of, sulphate of lime or gypsum will remain in the receptacle in which the mixture was made. Now all these thing are explained by the bringing together of the sulphuric acid and the carbonate of lime, since the former having a

greater affinity for the lime-base than the latter, drives it off and the operation is at an end. The train of circumstances looks backward for its explanation.

In the case of Arcella this is not so. It, too, no doubt, produces gas, but not for the mere pupose of producing it, nor for the purpose of uniting two chemical substances with one another. It forms gas because that is its means of overcoming a problem in locomotion which has presented itself. Hence the formation of the gas loks forward for its explanation, in other words it is one which has a telic explanation and looks towards an end and that end a link in a chain of events, for the Arcella makes the gas, no doubt, in the first instance, in order that it may turn right side up, but chiefly in order that it may resume the even tenor of its ways which have been temporarily interfered with by the accident which laid it on its back. We may, if we like, say that it is adapted to get right side up again by this process, but if we do, we must not suppose that we have then explained all that requires explanation, and if we do use that phrase we may remember that no one ever talks about carbonate of lime being "adapted" to make gypsum and consider why the terminology which we think suit-

able in the one case should be inappropriate in the other.

Since the evidence for the thesis which we are maintaining is cumulative we shall find it convenient to pause every now and then and consider, even at the risk of repetition, the bearing of the facts which we have been dealing with upon the main problem.

So far in this chapter we have been dealing with very lowly forms of life and that because, *ex hypothesi*, they are nearer the beginning of things living. Even amongst them we are confronted with happenings which it seems impossible to explain on causo-mechanical lines.

How much more so when we ascend the scale of the animal kingdom! Let us briefly consider a few cases often quoted in connection with the discussion as to Reason and Instinct, a matter not to be dealt with in this book. Consider the Bee—the instance is almost musty from quotation but can hardly be too deeply

The bee

pondered. Reaumur * tells us that hardly are the wings of the young bee dry before it sets out on its quest for wax, returning laden to the hive. There it proceeds to construct its cells, the form of which is exactly what it should be to give a maximum of strength and capacity

* *His. des Insectes*, t. v. mem. xi, teste Gerard, *Science and Scientists*, C.T.S., 1899, p. 108. The other quotations respecting insects are from the same work.

with a minimum of material. The author just quoted proposed the following problem to a mathematical friend: "To find the construction of a hexagonal prism terminated by a pyramid composed of three equal and similar rhombs, such that the solid may be made of the least quantity of materials." The value as calculated by the bee—for it is the problem which that insect had to solve—of the angles are 109° 28′ and 70° 32′. The angles found by the mathematician were slightly different from those worked out by the bee. Further examination disclosed the fact that the logarithm book used by the investigator was inaccurate and the angles used by the bee were correct. Or again, consider the case of the insect known as Sphex which lays its eggs near a caterpillar which it has paralysed, but not killed, by puncturing its nerve ganglia—a most delicate surgical operation—thus providing a supply of food for its future offspring.

Pass to another and higher part of the living world and consider the mysterious movements of eels, only cleared up of quite late years and, **Eels** as Professor Thomson very rightly says, quite inexplicable on the Machine Theory.* These creatures begin life close to the edge of the 500-fathom line to the west of Ireland and after

* See his *Introduction to Science*, p. 150.

passing a very early existence, the details of which are unknown to us, each rises to the surface as a transparent, knife-like, large-eyed creature known as *Leptocephalus.* In this stage it swims about and apparently never feeds, and becomes gradually transformed into the *glass-eel*, a creature shaped like a knitting-needle and about three and a half inches long. After a year it passes up with some millions of other *elvers* into the fresh waters of some river, and there as we all know it abides as the familiar *eel* for some years. If it does not succumb to the night-line or any other device of its foes, after a few years it sets out once more for the sea, becoming silver-coated and large-eyed on its way. Its journey is for breeding purposes. It travels enormous distances, for the eels from the Baltic rivers have, it is said, three thousand miles to traverse. Why? Because the Baltic waters are too cold and those of the North Sea too shallow for its purpose. Arrived at the spot of its desire it is assumed that breeding takes place, but one thing seems pretty sure, namely, that the eel never returns. How can this be explained on mechanical lines? It is difficult to see. Biologists tell us that the eel is really a deep-sea fish which has taken to colonizing fresh or brackish waters just as the salmon is a fresh-

water fish which has taken to spending its holidays in the sea, and that all such creatures return to their original habitats for breeding purposes, and no doubt all this is quite true. But pure mechanism does not explain it. It can tell us how the eel gets to the river and back to the sea; at least it can give us much information on this point, but it certainly cannot tell us why it does it, which, after all, is the main question. Finally, amongst a myriad instances, let us consider the strange case of the Lemmings. These little creatures, **Lemmings** which are not unlike water-rats, live on the eastern side of Norway but "at irregular periods, varying from three to ten years, a large portion of them set forth on the most mysterious of pilgrimages. Their course is directed due west, and thus does not lead them to the regions where more plentiful food might be obtained in the south. They spend more than a year moving resolutely on, turning neither to the right nor to the left for any obstacle, swimming lakes and climbing houses which lie in their path. They winter beneath several feet of snow, and rear families on their journey. All the way along they are accompanied by another crowd of travellers, for whose movements their migration is the signal. The Fox, the Stoat and the Hawk find a ready livelihood

provided for them in the ranks of the caravan; the Great Snowy Owl is on these occasions alone found in its best condition: even such pacific animals as Reindeer and Goats develop ferocity in presence of the Lemming, stamping them to death, and, according to some authorities, actually devouring them. All this makes it hard enough to understand what benefit this migration brings to the migrants, but it is all as nothing with the final issue. Steering ever west, the Lemmings arrive at last at the shores of the Atlantic. This obstacle they treat like the others. On the first calm day they plunge into the sea and the whole multitude perishes to its last member, the front of the host still pointing to the west. As Mr Romanes * tells us: "'No faint heart lingers on the way, and no survivor returns to the mountains.' So vast are the numbers thus immolated that in November 1868 a ship sailed for fifteen hours through a swarm of swimming Lemmings."† The habits described for the two kinds of insects were obviously beneficial for themselves and for their race; those of the eels we may assume are also at least not harmful; those of the Lemming are simply annihilative, and much ingenuity has been shown, not, it must

* *Mental Evolution in Animals*, p. 283.
† Gerard, *op. cit.*, p. 126.

be confessed, with the slightest success, in attempting to account for their racial suicide. But this at least seems clear, that these things are not susceptible of explanation under any purely Mechanical theory.

Homogeneous Matter and Local Motion, which are the sole factors relied on, cannot even explain the operations of Chemistry; for example they afford no full and adequate explanation of how it is that after all sorts of transformations and re-transformations there is a recurrence in any given body of all the collection of properties which it possesses, such as weight, affinity, crystalline form and the like, which though they are quite independent of one another, are always found to be united. Still less can it explain the far more complicated problems of living things.

Hylomorphism

The scholastic philosophy relies on a Hylomorphic explanation which teaches us that all bodies are endowed with substantial unity and are specifically distinct and that they possess active and passive powers which belong to them in virtue of their substantial essence and are indissolubly bound up with it. Further that they have an inherent tendency to realise by the exercise of their native energies certain special ends.* As to the earlier part of this

* Here and elsewhere, when stating the scholastic position, I have relied, for the most part, on the actual language

statement, it may be said that it is a mere formulation of facts. So much the better for the statement. As to the latter part, however, in which the real point lies, that no doubt will be dismissed by many as "mystical," or as an assumption. Let us at once dispose of these phrases. It is fashionable nowadays to call explanations of this kind "mystical" or "supernatural," and imagine that they have been thereby disposed of. But either there is or there is not an element of this kind in nature. If there is not; *cadit quæstio*. If there is; it is not supernatural.

And now as regards an "assumption"; no doubt it is that in a sense. But is it an assumption which can be proved directly or indirectly?.

If at any time we set ourselves to the consideration of possible *viæ mediæ* we shall I think, be forced to the conclusion that in the case of the problem which we are considering we have arrived at what the logicians call a *Dichotomy*. Either these thing are effected by by mere Matter and Motion or there is a something over; an *entelechy*, to use the Aristotelian phrase. If we are to rely solely on Matter and Motion we must bear in mind that we must

of the English translation of Cardinal Mercier's Manual, since it is an authoritative work.

take them as "given," since we do not know how they came to be. We begin within a system and, as we allow no telic factor, we must leave Blind Chance to account for things. Can it do so? To believe it seems to me to require more credulity than it would to swallow all the Pantheon of Olympus. Dr Johnstone is abundantly right when he says * that the factor we have been speaking of is "forced upon us mainly because of the failure of the mechanistic hypotheses of the organism. If our physiological analysis of the behaviour of the developing embryo, or the evolving race or stock or the activities of the organism in the midst of an ever-changing environment, of even the reactions of the functioning gland, fail, then we seem to be forced to postulate an elemental agency in nature manifesting itself in the phenomena of the organism, but not in those of inorganic nature. This argument, *per ignorantiam*, possesses little force to many minds: it makes little appeal to the thinker, the critic or the general reader, but it is almost impossible to overestimate the appeal which it makes to the investigator as his experience of the phenomena of the organism increases, and as he feels more and more the difficulty of describing in terms of the Johnstone

* *Philosophy of Biology*, p. 318.

concepts of physics the activities of the living animal."

The *entelechy* of Aristotle, or in these later days of Driesch, or the "elemental agency" just mentioned are other terms for what the scholastics call the *anima vegetalis* or *sensitiva*, according to whether the vegetable or animal kingdom is under consideration, and in either case as the "Form."

And one last word on this point:—the Luminiferous Ether is a collection of apparent antinomies postulated to explain the undulatory theory of light, and, as Sir Oliver Lodge says, gives itself away only by the perfectly uniform manner in which it transmits not only light but other things, such as electric and magnetic waves. Is there really more evidence —even as much evidence—for the Ether as there is for the Entelechy?

CHAPTER X

REPAIRS AND REGENERATION

Experiments on Hydra and other forms.

Repairs

One of the most remarkable powers of living matter is that which it possesses of making its own repairs, of mending itself where it has been damaged, and, in certain cases, of reconstructing large portions of the body which have been destroyed or separated from it.

In some form or another this power belongs to all living matter and when we watch a wound heal in ourselves or in any animal we see a minor example of the process of regeneration. The experimental study of this subject has been one of the most fruitful paths of scientific research during the past quarter of a century, and the more important results which have been obtained have been embodied in a very interesting work by Professor T. H. Morgan.*

The power in question is one which is met with in plants and in animals and amongst

* *Regeneration,* Macmillan Company, 1901.

the latter finds examples even of its major manifestations both amongst vertebrates and invertebrates.

Over the phenomena as exhibited in the vegetable kingdom we need not delay, for most people will be familiar with the manner in which begonias may be propagated by means of very small portions of the parent plant, from which entire specimens are reconstructed, and everybody, however ignorant of horticulture, must have seen cuttings being " struck," that is to say fragments of a plant, say a carnation, set in the ground and gradually constructing for themselves roots so as to become complete plants.

It will be more interesting to devote the space which can be allotted to this part of the subject to a consideration of some instances from the animal kingdom and we may commence with the classical instance of the Hydra.

Hydra

The Hydra is a small fresh-water creature, of a bright green colour and somewhat resembling a sea anemone, though very much smaller and of a more elongated build. It was on this creature that Abraham Trembley (1700-1784) carried out his classical experiments in 1740, showing first of all that if the polyp was cut into two pieces each of those two pieces became a new and complete polyp.

It was known, of course, at this time that plants could be multiplied by a cutting process, and Trembley seems at first to have been undecided as to whether he ought not to consider the hydra a plant, because it also could be multiplied in this way. However, his observations on its methods of feeding and its power of movement brought him to the conclusion that it was in truth an animal and that his discovery revealed a new and hitherto unknown power of animal life. "I felt," he says with commendable modesty, "strongly that nature is too vast, and too little known, for us to decide without temerity that this or that property is not found in one or another class of organised bodies." Trembley continued his experiments, which have constantly been repeated and verified in the years which have passed since his death. He found that a Hydra could be divided into a number of pieces, and that each bit would, under favourable circumstances, develop into a new and complete creature. He also found that if the head-end was bisected, the result was the formation of a two-headed Hydra. Moreover, he found that he could again and again bisect these heads until he had an eight-headed Hydra with a single stalk or lower portion. It is clear that this lowly, or comparatively lowly, form

of animal life has powers of regenerating itself which are not inferior to those presented by plants.

Earth-worms

Another experimenter was Spallanzani, whose name has already come before us in connection with the question of spontaneous generation. Spallanzani experimented on earth-worms and showed that they possessed powers like those of the Hydra, though not so extensive, for whilst the earth-worm, if divided transversely, will produce a new head or a new tail, if divided longitudinally it dies.

But Spallanzani's most important experiments were those made upon the Salamander, for this is a vertebrate animal, very much higher

Salamander

in the scale of nature than those with which we have been concerned up to now. He found that if the tail was cut off a new one would grow which would contain vertebræ—new vertebræ, of course—just like those which had formed the skeleton of the original appendage. Further, he showed that if a leg, or even all four legs were cut off, it or they would grow again and that this process might be repeated time after time.

In one experiment which he carried out, he six times removed all four legs and the tail from one Salamander during the three summer months. The unwearied animal reconstructed itself on each occasion and even on the last

occasion the process of reconstruction took place with the same rapidity as it had done on the first. Spallanzani calculated that during these three months the animal under experiment had made for itself no less than 647 new bones, not to speak of all the muscles, nerves and arteries which formed with the bones in question the various parts which were restored.

Spallanzani also found that the Salamander could regenerate its upper and its lower jaws if these were snipped off. It is obvious, therefore, that an animal of quite high position in the scale of nature may possess very remarkable powers of repair. It will be noticed that there is one very important difference between the phenomena exhibited by the vertebrate and by the invertebrate and that is that the former cannot be so divided as to constitute from it two complete forms. There is then limitation of the powers possessed by the more lowly form. On the other hand its reconstructive abilities are much greater than those which are possessed by any mammal. The mammal can heal up a wound if that wound is not of so serious a character as to cause death, but it cannot re-grow even a joint of a lost limb, much less reproduce the entire member as the Salamander or Newt can.

A further remarkable experiment has been made upon the eyes of the larvæ of the Triton or waternewt by Wolff.* This observer removed the crystalline lens from the eyes of Triton larvæ, performing upon them, in fact, the operation known as "couching" in cases of cataract. He found that the animal was capable of regenerating its lens and did regenerate it in a few weeks. Sometimes it happened that a fragment of the old lens had been left behind and in these cases it was from this that the new one grew, a state of affairs which one can well understand. But in other cases a most remarkable state of affairs came under notice, for the new lens was reconstructed from the epithelium of the border of the iris, that is to say the coloured curtain, which in our eyes is blue or grey or brown. To the ordinary reader this will not seem more remarkable than any of the phennomena which have been already narrated and perhaps less remarkable than some of them, but to the embryologist it is a truly wonderful thing.

The newt's eye

The lens and the iris are originally formed from wholly different layers of the developing embryo, so that when a new lens is formed from the iris is is being made not only in a way but from a material in which and from which

* *Arch. f. Entwickl.-Mech. d. Organismen*, bd. i., 1895.

no lens ever was made before so far as we know or indeed can imagine. Hence this experiment shows the restorative powers of the triton organisation in a most remarkable manner.

It is scarcely possible to overestimate the importance of this crucial experiment, but the following quotation from Driesch * will emphasise this fact. "In the year 1894 Wolff followed his critique" [on Darwinism] "by an experiment which was expressly undertaken as a solution of the question: Darwinism or Teleology? His aim was to see whether an organism could restore an organ extracted from it for the first time in its development, and to examine how this restitution was accomplished. 'Primary finality' was to be proved by the positive outcome of the experiment, which would, on the one hand reduce Darwinism *ad absurdum* and, on the other through the fact of purposive adaptation, go to support teleology in a very significant form." [The experiment described in the text is then detailed.] "Thus was 'primary finality' demonstrated."

A few further examples of this kind amongst invertebrates (where the instances are legion) may now be detailed.

Observers of the common objects of the sea-

* *History*, p. 175.

shore can scarcely have failed to have seen specimens of the creature called Tubularia. It has a stem, the base of which is embedded in the sand and a head-end surrounded by a ring of tentacles and provided with a sort of proboscis. Almost anything can be done with this creature in the way of regeneration. If the head be snipped off the base will grow a new head and the head a new base, just as a worm chopped in two will do. If instead of cutting it the animal be pulled up by the roots and replanted head downwards the head-end develops roots and the root-end becomes a head with tentacles and proboscis.

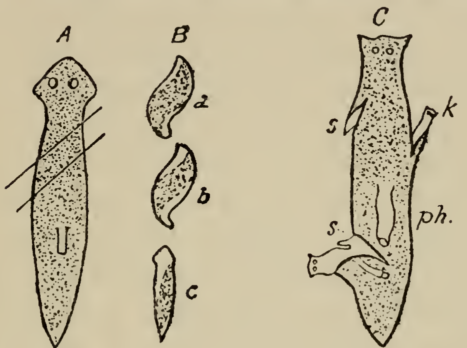
Tubularia

Finally, if we snip off the head and tail of the polyp and hang it up horizontally in the water by a thread, it will grow a head from either end.

Another creature Planaria, a parasitic worm, can be cut up into a number of pieces all of which will develop into complete individuals. Moreover like the Hydra it can be partially bisected and will then grow into a kind of two-headed Nightingale amongst Planarians, with a single body and two heads. More wonderful still if oblique cuts be made into the sides of the body new heads or tails will grow from them according to the direction in which the incisions have been made (fig. iv.).

Planaria

Now in all these cases, wonderful as they are, it will be noticed that the new formation has grown directly from the organised substance of the old. This is remarkable enough in all con-



Regeneration of Planarians. A. an animal divided into three parts by two oblique cuts. B. the fragments (a.b.c) in process of regeneration C. an animal with various oblique incisions in the margin of the body, which have induced the new formation of heads (k), of tails (s), and pharynx (ph). A and B after Morgan; C after Walter Voigt.

Fig. IV.

science. To translate it into the language of machines one has to imagine a locomotive engine, which has been in a bad break-down, setting to work to grow for itself a new wheel or to construct a new connecting-rod. Or we

may picture a lathe which has had a wound inflicted in its side setting to and producing a new chuck from the incision.

This would be wonderful enough and is hard enough to imagine, but still more difficult of mental imagery would be the state of affairs in which the wounded locomotive should resolve itself into its constituent steel and brass, and having done so should then, by the force of its own intrinsic powers, reconstruct a full, complete and working railway-engine. Yet this is what is done by another form and the whole chain of occurrences is so remarkable and so forcible an example of the powers of living matter, as well as of their differences from those of non-living objects, that it may be given here at length.

The observation in question was made by Driesch * who is that rare combination of qualities—a professed philosopher and a biologist of the first rank. It deals with Clavellina lepadiformis, a tolerably highly organised creature belonging to the class of ascidians placed by zoologists very near the lower vertebrates in the scale of animal life. It is about an inch in length and its body is divided into three portions, the uppermost of which forms an extraordinarily large, basket-like gill,

Clavellina

* *Arch. f. Entwickl.-Mech. d. Organismen*, xiv., 1902.

provided with an entrance and an exit for the water.

To this succeeds a small connecting body portion which contains part of the intestines and finally there is the so-called intestine-sac with stomach, intestine, heart, reproductive organs, etc. If we divide the body of a Clavellina at the level of the connecting portion, so that the gill-basket and the intestinal-sac are separated from one another, either or both of these two portions can in three or four days complete itself into an entire organism, since by means of true regeneration proceeding from the incision, the gill-basket makes itself an intestinal-sac and the intestinal-sac a gill-basket.

With this process we have already become familiar, for it is the kind of thing which we have studied in the Hydra and in the earthworm, but the process of reconstruction sometimes takes place in quite a different manner, and this is especially the case in smaller individuals. In these cases reconstruction begins not by a process of renewal but by one of regression.

The organisation of the gill-basket, its ciliated clefts, its openings, etc., all gradually dwindle away. At the end of five or six days no more organisation is to be seen in these

parts, which appear like white spheres, in fact the describer states that when he first saw this condition he came to the conclusion that the clavellina was either dead or on the way to death. It was not so, however, for though the creature remains or may remain in this condition for two or three weeks, at last the day comes when it begins to clear and to stretch and then after the end of two or three days it is found that amorphous mass has once more become a complete ascidian with gill-basket and intestinal sac. It has become a perfectly new organism which has no continuity with the parts of the earlier organisation though it has with its material. Its gill-basket is not a derivative of the old one; it is very much smaller and has fewer and smaller openings. What has happened is that the old organised gill-basket has returned to an indifferent substance and then, from this indifferent substance on embryological lines, a new smaller individual has been constituted. But this is not the whole story, for it is not merely the isolated gill-basket which can restore itself by means of this roundabout process, but after having isolated the basket, it can be itself divided either into an upper and lower portion or into an anterior and a posterior bit and each of these portions will then go through the

same process, that is each of them will first of all return to the indifferent condition and then from that re-constitute itself into a new small ascidian.

Here then is a series of events which, if they could be imagined to take place in connection with a machine, could only be described in the way attempted above by supposing that the machine had resolved itself into its constituent metals and from these metals rebuilt itself into a new machine.

Assuredly these phenomena seem to point to the existence of some special energy or force intimately present throughout the entire living organism, unifying its various parts, dominating their activities, directing the evolution of the being as a whole towards a definite prefixed end, which, according to the old view was just the function of the "Vital Principle"—in other words, the "Form"* of the Scholastic Philosophy.

It is extremely difficult to imagine any theory which will account for the phenomena of regeneration on purely chemico-physical lines, since they, like the phenomena which we studied in connection with the developing ovum, so clearly point to the existence of a

* Life viewed as a *principle* was *forma* vel *causa formalis;* viewed as activity or *operatio* it was *causa finalis* of the Being.

directive force in living matter which has no parallel in non-living substances.

What they amount to

Nothing proves this more clearly than the kind of explanation which is attempted to be given by those who deny the existence of the power in question. Amongst these the most prominent of recent writers is Professor Weismann. We have discussed the question of "adaptations" in a previous chapter and here again we find ourselves confronted with the same explanation in connection with regeneration. Professor Weismann, for example, speaking of the behaviour of the tubularian which we have just been considering says, as elsewhere quoted:—"This also appears to us to be adaptive, and does not surprise us, since we have long been accustomed to recognise that what is adapted to an end will realise this if it be possible at all." There is a sense in which all this can be read in perfect consonance with the scholastic theory. The "form" is adapted to an end; the end of accomplishing what the organism which it "informs" was intended to accomplish; it is very doubtful whether Weismann himself would be willing to accept the full significance of his words; but it is well to be quite clear on this matter as want of clearness is at the bottom of half the misunderstandings which exist on this fundamental

Adaptations

point. Vitalists have no quarrel with the attempt to explain all kinds of operations in the living being according to the laws of chemistry and physics. They admit to the full the claim that all or nearly all these operations involve the invocation of these sciences. There is the further claim, that these factors explain the whole matter. That, in the opinion of Vitalists they cannot do. Something further is needed, and that something to them is the entelechy, or, in scholastic language, the "form." Even the most mechanistic of writers—materialist if the phrase is preferred—have gone a long way towards admitting what has just been urged. We have just been alluding to Weismann, and may add that in another passage he makes the following very significant remark:—"It would be a great delusion if anyone were to believe that he had arrived at a comprehension of the universe by tracing the phenomena of Nature to mechanical principles. He would thereby forget that the assumption of eternal matter with its eternal laws by no means satisfies our intellectual need for causality." * Such a statement, though exception might be taken to the word "eternal" as applied to matter, could be made by the most orthodox vitalist of the scholastic variety. In another

* *Studies in the Theory of Descent*, vol. ii., p. 710.

place the same writer urges, quite properly from our point of view that a belief in mechanism does not exclude a belief in teleology.

Teleology

That is just what we are urging here; mechanism and teleology are not mutually exclusive. Mechanism is the way in which the "telic" factor attains its end: let us hear Huxley on this point, for though he would not accept the Theistic position he saw its strength. "The more purely a mechanist the speculator is, the more firmly does he assume a primordial molecular arrangement of which all the phenomena of the universe are the consequence, the more completely is he thereby at the mercy of the teleologist, who can always defy him to disprove that this primordial molecular arrangement was not intended to evolve the phenomena of the universe."* See also p. 187:—"It seems to me that "creation" in the ordinary sense of the word, is perfectly conceivable. I find no difficulty in imagining that, at some former period, this universe was not in existence; and that it made its appearance . . . in consequence of the volition of some pre-existent Being. The so-called *a priori* arguments against Theism, and, given a Deity, against the possibility of creative

* *Life of Darwin*, ii., p. 201.

acts, appear to me to be devoid of reasonable foundation."

To quote a more recent writer, it may be noted that Professor Scott * specifically states that "acceptance of the theory of evolution by no means excludes belief in a creative plan." But, indeed, none but the shallowest brain could support any other contention than this.

The acceptance of the "adaptation" explanation then depends on what its content is. It may be a purely verbal explanation; in the mouths of some at least, it is no more. It may be an explanation entailing the whole of the vitalistic theory. In that case, from our point of view, it is satisfactory so far as it goes.

* "The Theory of Evolution," Westbrook Lectures for 1914.

CHAPTER XI

REGENERATION AND ITS SIGNIFICANCE

Further instances in Experimental Embryology—Their significance—Driesch's Harmonious-Equipotential System—His Complex Equipotential System.

The facts of regeneration are amongst the most significant in relation to the vitalistic controversy, and a further chapter must be devoted to considering them in conjunction with some further observations in experimental embryology—that very recent but most important branch of scientific work—and with the important conclusions drawn from these in the writings of Driesch.*

Driesch

In Chapter VII. we learnt something about

* It would be tedious to give the source of each individua. quotation in what is to follow, and the following list of works on which the ensuing pages are based is given once for all It will be observed that no mention is made of Driesch's numerous papers in German. The ordinary reader of German may be warned off these, for so difficult are they of comprehension that the present writer freely admits that he never fully grasped Driesch's meaning until he read him in English. Fortunately, the folowing works include all his ideas: (1) *The Science and Philosophy of the Organism*, Gifford Lectures 1897, A. and S. Black. A monumental work. (2) *The Problem of Individuality*, Macmillan, 1914, in which the theories dealt with in this chapter will be found in perhaps their easiest form. (3) *The History and Theory of Vitalism;* same publisher and date.

the early history of the embryo—that it usually consisted of elements derived from two parents of different sexes; that the originally single cell divided into two; that each of these again divided, and so on. The result of these continued divisions is to convert the originally single cell into a mass of cells all derived from it. This solid mass of cells suggested the appearance of a mulberry to its first describers and consequently received the name of *Morula*. Then by processes which cannot be detailed here, this solid mass becomes a hollow sac which we may think of as being very like a raspberry when we have pulled away its stalk and the uneatable part that goes with it, and if we imagine the hollow spheroid closed into a ball at the hole left by their removal. At this stage it is called a *Blastula*, and we need not follow it further, except to say that in higher forms differentiation sets in so that the different organs of the adult body are developed from what was once an indifferent mass of cells.

It will be remembered that it was shown to be possible to shake apart the cells of the developing morula of Amphioxus so that in place of the single individual which they would normally have formed, a collection of—say—eight will be formed. To put it in another way each of these first eight cells (it may be more,

but we will take eight) has two potencies—(i.) it may become one-eighth of a single Amphioxus; or (ii.) it may become an entire Amphioxus. We shall see the very important bearing of this in a short time.

Twins

Here it may be said that this observation seems to throw an important light upon the question of twins. Human twin children are of two varieties—not sexes in this connection—homologous and heterologous. Homologous twins are always of the same sex; practically invariably very like one another in apperance, and are contained *in utero* in the same bag of membranes. The other variety may be both of the same sex or of different sexes; they are not necessarily any more like one another than members of the same family commonly are, and they have separate bags of membranes.

It has been thought, and probably correctly, that the homologous twins are the product of a single ovum which has, for some reason still unknown, undergone a division of multiplication before pursuing the ordinary course of a division of development.

Further, it is probable that the explanation of such curious things as Siamese Twins and Two-headed Nightingales is that the ovum has undergone an imperfect division of multiplication before proceeding on its normal course of

division.* These experiments and others to be shortly alluded to seem to dispose of what is known as *evolution* in the ovum, and to establish *epigenesis*.† There have always been two theories as to the impregnated ovum,‡ the first of which—evolution—assumes that the new individual is contained in the ovum as such and only requires unfolding. The extreme view of this was to be found in the ancient and, since the discovery of the microscope, exploded theory of *emboîtement*. According to this, each generation in perpetuity was contained in any ovum, an idea which involves an obvious absurdity. But it exists in another form, that is, under the idea that the embryo exists, so to speak, in the form of a developable machine and that the process, though not so crude as that just alluded to, is none the less a process of unfolding a new but preformed individual. The other theory implies—to put

Evolution and epigenesis

* Heterologous twins under this theory are the product of two ova—a case of superœtation.

† Evolution in this connection has nothing whatever to say to evolution in the commonly understood or Darwinian sense.

‡ Apart, of course, from the old divisions of *Spermatists* and *Ovulists* of historic interest only since the microscope came into existence. The former—to put things simply—looked upon the spermatozoon as the plant and the ovum as the pot in which it grew; the latter thought that the ovum was the important factor and that the spermatozoon merely incited it to action. The latter view, under another form, has recently come into some notice, as will be seen when the question of *Parthenogenesis* comes under consideration.

the matter in the briefest possible way—a new formation. A little thought will show that this is a vitalistic view—" all believers in epigenesis are Vitalists," says Driesch.* Now, if, as has been shown, it is indifferent to the first cell as to whether it becomes one or eight, or more individuals, it is clear that the process of development of the embryo cannot be one of evolution or unfolding, but must be the formation from indifferent material of a new individual. However, let us go a step further. The first and—though it took some time for the fact to be recognised—epoch-making experiments in this connection were made by Roux and published in *Virchow's Archiv.*† I was myself at that time engaged in studying the problem of double monstrosity, and at once saw the important bearing which Roux's observations had on that question. I dealt with them in an article‡ which was, I think, the first to call the attention of English readers to the matter, since the periodical in which Roux's conclusions appeared appealed more to medical than to purely scientific readers. The experiment was as follows:—Roux very carefully

Roux's experiment

* In his *History*, p. 37, where a short account of the controversy and its protagonists will be found.

† Vol. cxiv.

‡ *Journal of Anatomy and Physiology*, vol. xxiii. On the Origin of Double Monstrosity.

pierced with a hot needle one of the two cells formed by the ovum of the frog as the result of its first division. If the experiment was successfully carried out, the ovum did not perish, but the uninjured cell went on with its development with the result that a half-embryo was formed. A little thought will show that this experiment seemed to be a proof of preformation, for it could be argued from it that the very first division of the ovum divided the developing individual into its two lateral halves. So matters remained until 1891, when Driesch repeated Roux's experiments on the egg of the common sea-urchin. Here diametrically opposite results were obtained, for instead of the half-embryo, a complete but small embryo resulted. Moreover, even in the next or four-cell stage, two or three of the cells could be destroyed yet a small but still perfect embryo resulted. Further, later experiments on the egg of the frog have shown that if the cell is given an opportunity for a certain rearrangement of its protoplasm, there too a complete but small embryo will result. The evidence then instead of being contrary to epigenesis is entirely in its favour. One last series of experiments and we can turn to the consideration of the bearing of these observations on the question of Vitalism.

These were made on that favourite subject of research, the developing ovum of the sea-urchin. This forms a blastula of about one thousand cells—a hollow sphere as we have seen. If, with a pair of very fine scissors, this blastula is cut up into bits, in any direction but so that no fragment is less in size than one quarter of the entire blastula, each such bit will go on developing and will form a complete, though small, larva. Now let us turn to the bearing of these experiments. Driesch very properly says that *one* proof is sufficient. "A truth is either proved or not proved; and, if it is once proved, it is not necessary to prove it further," * and the first and most important of his three proofs is based on the experiments which we have been considering. This must now be detailed in a paraphrase of his own words.† Fragments of the blastula, as well as the first two or four cleavage cells can give complete embryos even though the former fragments are cut quite at random. The prospective potency then not only of the first two or four cleavage cells but also of all the thousand cells of the blastula must be the same. To a collection of cells each of which has an equal prospective potency he gives the name

Dreisch

* *Problem of Individuality*, p. 20.
† Chiefly from the work just quoted, pp. 13 *seq.*

of an "*equipotential ontogenetic system*": the blastula is such a system. Further, "in the blastula each element is equally able to play any single part in the formation of one totality. Any particular cell would have played another single part, had you cut the blastula in some other direction; it can play any single part required. And what it actually does in the special case—normal or experimental—is always in *harmony* with that which is done by its fellow-cells, which possess the same great potentiality as itself. Let us then call our blastula an *harmonious-equipotential system*."

The existence of such systems is Driesch's first and most important proof of vitalism, and a little consideration will show that in previous pages we have been studying various things which come under this category, such as Tubularia, earthworms, and the branchial apparatus of Clavellina which, as Driesch says, "is the very type of a harmonious equipotential system; each element of it is able to perform any single morphogenetic action that is required and all the elements work together in harmony in each single case. For the cut can be made quite at random." Let us complete the matter in Driesch's own words—they cannot be improved upon—"If normal undisturbed embryogenesis alone would result in the

formation of a complete embryo, if, in other words, all the experiments carried out with early embryonic stages would result in the production of fragments of organization, then we should feel obliged to accept the theory of machine-like preformation. But this is not the case. On the contrary, the ontogenetic systems are 'harmonious-equipotential.' Take whatever portion of them you like, quite at random, and *yet* there will be completeness of final organisation. The embryonic 'machine' then, that is supposed to exist in the normal

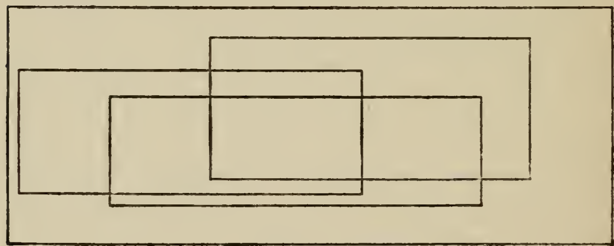


FIG. V.

Reproduced by permission of Messrs Macmillan & Co., Ltd., from the "Problem of Individuality" by Prof. Hans Driesch.

The harmonious-equipotential system (H.E.S.). The large rectangle represents an H.E.S. in its normal undisturbed state. It might *a priori* contain a very complicated kind of "machine" as the foundation of development. But any fragment of the system (the small rectangles and innumerable others), contingent as to its size and to its position in the original H.E.S., is equally able to produce a small *but complete* organism. On the basis of the mechanistic theory, then, any fragment of the H.E.S. would contain the same "machine" as the original system. This is absurd.

system, would be obliged to be present in its completeness in one *part* of the system also, and also in another such part, and yet in other such parts too, and equally well in parts of different size, overlapping one another (see fig 5).

For we know that *any* part of the system, contingent as to its size and as to its position in the original system, can give rise to a complete being. *Every* cell of the original system can play *every* single role in morphogenesis; *which* role it will play is merely a 'function of its position.' In the face of *these* facts the machine theory becomes an absurdity. These facts contradict the *concept* of a machine; for a machine is a specific arrangement of parts, and it does not remain what it was if you remove from it any portion you please. Now the machine theory was the *only* possible form of a mechanistic theory that might *a priori* seem to be applicable to the phenomena of morphogenesis. To dismiss the machine theory, therefore, is the same as to give up the attempt of a mechanical theory of these phenomena altogether. Or, in other words, the analytical discussion of the differentiation of harmonious-equipotential systems entitles us to establish the doctrine of the *autonomy of life*, *i.e.*, the doctrine of the so-called vitalism, at least in

a limited field: there is some agent at work in morphogenesis which is not of the type of physico-chemical agents."

Ovary and ova

Germane to the proof which we have just been considering is that drawn from the ovary which constitutes what Driesch calls a *complex-equipotential* system. The ovary contains the ova from which succeeding generations are to arise. Does each egg contain a "machine"? How can it do so when we consider that before it has come into existence it has had to undergo an enormous number of divisions? Surely it could not divide and divide and—being a machine—always remain the same? Remember too that the machine—since the adult organism, a tremendously complicated thing, has to arise from it—must itself be an enormously complicated machine.

Of course, it may be argued that the *Anlage** of the ovary is not a machine; but those who make this assertion have to show us how it is that in the course of its divisions and when the last, by which the egg is produced, has arrived, a machine is the result. Where does that machine suddenly make its appearance from? "Thus it follows that our problem

* There is no real substitute for this German word which is now quite familiar to scientific readers. It means the early substance from which any particular organ or part is formed—the tiny bud, so to speak, from which the full blossom arises.

must either be accepted as an independent proof of vitalism, or be reduced to the problem of morphogenesis without machine-like preformation, *i.e.*, the problem of harmonious equipotentiality already discussed."

We have now considered two of Driesch's three reasons, those which are germane to the present point in our inquiries, and the more they are pondered over the more unanswerable they will appear.

But we are by no means at an end of our inquiries, for there are other difficulties to be met and other lines of argument to be considered.

In the next chapter we shall again traverse most of the ground of this chapter, but we shall do so in a different way and for the purpose of looking at the same facts—and, in a measure, the same proofs, from a different point of view. This must be pardoned since it may be expected that some of the readers of this book may find—from unfamiliarity with biological discussions—that it is not easy to follow these arguments. Those which are now to be submitted may help to clear matters up.

CHAPTER XII

LIVINGS THINGS AND MACHINES

Living Things and Machines—Their Differences—Spencer and Weismann—A "Verbal Explanation."

We have now studied a number of the fundamental activities of living bodies and have seen that they include many features which are not discoverable in non-living substances. That there may be a superficial similarity between some of the circumstances of the two kinds of matter may possibly be conceded, but when carefully examined it seems that the fundamental differences are far greater than the surface resemblances.

Living thing and machine

"The structure of a machine," says Strasburger,* a very distinguished German botanist, "might be called its organisation; and the fact that, when provided with a store of energy, it can be started by the opening of a valve to perform work conformable to its structure—this property might be called its sensibility. But the living substance is entirely distinguished from the dead machine by the ability to provide itself with the energy needful for

* *Das Protoplasma und die Reizbarkeit,* 1891, s. 24.

its work; to set itself in motion and keep itself going; to repair itself, within certain limits, the defect that may arise; and above all, by the fact that it constructs itself. In short, an organism—in contradistinction to the dead machine—is a living machine, one that does not depend upon external impulses for its movements, one that regulates its own course, and continues going as long as the environment will allow—only through the hostility of this or through irreparable misfortune is it brought to a halt."

The power to repair itself—here is a thing not met with or begun to be suggested in any machine. Professor Hartog * very acutely points this out in connection with the so-called automatic machines. He says: "In its original use 'automatism' designates the continuous sequence and combination of actions, without external interference, performed by complex machines designed and made for specific ends by intelligent beings: thus we speak correctly of 'automatic ball bearings' that tighten themselves when they become loose; but even these cannot take up fresh steel and re-deposit it, either to replace the worn parts or to strengthen a tube that is bending under a stress."

* *Op. cit.*, p. 12.

Hertwig

The difference between the living organism and a machine has been very carefully considered by Oscar Hertwig,* and as his reputation as a biologist stands deservedly high, it will be useful to quote him *in extenso*, rather than to give a catena of quotations from other persons. He commences by saying that it is the more necessary that this matter should be set in the proper light because there is a tendency at the present time to try and explain the living organism in the terms of a machine and to believe that organic operations can be accounted for in this matter. He himself maintains that very important differences exist between a living organism and a machine.

A machine can only operate in one or at most in a few directions and that in an unchangeable manner in accordance with its original construction. Its individual parts cannot, by their own power, rearrange themselves, or enter into new combinations in correspondence with the new conditions with which they may find themselves confronted. Therefore the machine cannot react to outer influences in a purposeful and many-sided manner. The organism, on the contrary, has an innate power of construction. The single cell, the first step in the direction of an organ-

* *Op. cit.*, s. 141.

ism, is irritable towards warmth and light as well as towards all kinds of mechanical and chemical influences and thus is responsive to the most manifold expressions of life. In the machine power is developed in a restricted direction, in the organism there is an extraordinarily free, many-sided play of powers.

Musical box and larynx

A comparison will make the difference between the two more obvious. Look at the difference between a musical box or a gramophone and the human larynx combined with the lungs and the nerves and muscles which set it in operation. Both of these can give vent to numerous tunes and those of all kinds. But the difference between them is enormous. The instrument can only play the tune or tunes which it is constructed to play or the records which are inserted into it. On the other hand, without any visible change the human larynx can pass from one melody to another and alter its tune and time by the action of the muscles under the influence of the will of the individual who is singing. Moreover, at will the singer can alter the pitch, the time and the tone of his song, introduce all sorts of trills and runs and modifications which the instrument can never do, for that must always perform its task in exactly the same manner.

Then we come to a second difference. When,

as the result of a stimulus, changes have taken place in the organism, say that a muscle has become altered in structure and tired by long use, it has the power, after a time of rest, to return to its former condition, so that on the stimulus being repeated it will be found that the muscle can respond to it as it did on the previous occasion. The machine, on the contrary, has no power of repairing injuries or wear and tear which may take place in it as the result of its ordinarly use ; it cannot lubricate itself or clean itself or make itself ready for new action.

And thirdly, no machine can beget a new machine nor has any one succeeded in constructing anything which, by division, will shape itself into two instruments where but one existed before. It is only and properly so in a living organism that we talk of irritability, of stimuli, of reflex actions, and it is a hopeless task to attempt to explain an organism on mechanical principles.

In a machine the movements of the rollers, wheels, levers and other parts can be explained on purely mechanical principles, but in the organism the operations of a chemical character, extraordinarily varied as they are, cannot be explained in this way.

Whilst in the machine the movements of the various parts are firmly united to one another

by their construction, so that they cannot alter independently of one another, the living organism can alter its structure and at the same time set aside bye-products without in any way interfering with its own existence or work. In the free play of powers to be met within the living organism lies a profound difference between it and the limited capabilities of the machine. Such, in paraphrase, are the views of the distinguished German biologist, and the differences on which he insists, one would have thought, would have been such as would have appealed to most observers. Such, however, is not the case, as we may easily see by referring to the books of those who uphold the mechanical theory and how difficult it is to justify that theory may perhaps be best seen by studying the explanations of their views which have been given by some of the most distinguished amongst them.

Mechanical explanations

Let us examine a few instances. Herbert Spencer * declines to admit the existence of a *nisus formativus* or vital force or principle, and is confronted with the necessity of accounting for the phenomena which he sees before him. How does he do it? He tells us that "the polarities of the molecules determine the *direction* in which the *power* (of environing

* See *Principles of Biology*, vol. i., App. D., p. 705.

forces) is turned." This explanation to the careless no doubt sounds to the full as satisfactory as did the blessed word Mesopotamia, but when we come to examine the meaning of the phrase we find that the explanation is not really an explanation at all.

"Polarities"

In the first place we may well ask, what are these "polarities"? They seem to be nothing more or less than our old friends the "adaptations," which in other words mean the powers of the cell. So that the sentence really means, the powers of the cell determine what it shall do under certain circumstances, which is just what we knew all along. This explanation is an excellent example of what Professor Ward * alludes to when he points out that the system of explaining everything which is "going" because it is "going" is admirable "once you have got inside the system," but has no claim to be looked upon as a full explanation. No doubt the cell does conform itself to circumstances by virtue of the powers which it possesses, but to call these powers "polarities" and then to suppose that you have explained how they came to exist and how they carry on their operations is to be guilty of the merest word-explanation.

The fact is that we must attribute the un-

* *Naturalism and Agnosticism*, ii., 271.

convincing character of so many scientific arguments to this very reason that those who put them forward forget or ignore the fact that they *are* within a system. Indeed, all purely materialistic explanations must be within a system, for none of them can explain the system itself, nor, it may be added, the formulator of the system, nor can say why the system or its formulator are either of them in existence.

Of course, it is perfectly true that many writers of the class to which I have been alluding are perfectly well aware of these facts, which indeed, one would suppose, were sufficiently obvious. Their attitude is very much that of Huxley:—we cannot know anything about the origin of the system; let us study such objective facts, if indeed there are any objective facts, which we find ourselves confronted with. There is nothing to be complained of in this as long as those of this attitude do not go further and try to persuade their readers that they have a *complete* explanation to offer them. Some do, however, make such claim, incomprehensible though it may be to some of us how they can do so. For example, take the following passage from Loeb's work, the main thesis of which is dealt with in Chapter XIII.:—"The idea that the

organism as a whole cannot be explained from a physico-chemical viewpoint rests most strongly on the existence of animal instincts and will. Many of the instinctive actions are 'purposeful,' *i.e.*, assisting to preserve the individual and the race. This again suggests 'design' and a designing 'force,' which we do not find in the
Loeb realm of physics. We must remember, however, that there was a time when the same 'purposefulness' was believed to exist in the cosmos where everything seemed to turn literally and metaphorically around the earth, the abode of man. In the latter case, the anthropo- or geocentric view came to an end when it was shown that the motions of the planets were regulated by Newton's law, *and that there was no room left for the activities of a guiding power.* Likewise, in the realm of instincts, when it can be shown that these instincts may be reduced to elementary physico-chemical laws, the assumption of design becomes superfluous." (*Italics mine.*) Is it possible that anyone can fail to see that the question of helio- or geo-centricism do not even touch that of "purposefulness."

Let those who have any temptation to forget the difference between the interior and exterior of a system, consider the parable of the "philosophical mouse" which we owe to another Dr Ward.*

* W. G. Ward, of Oxford Movement fame, in his *Philosophy of Theism.*

This intelligent animal had lived all his life in common with the rest of his tribe within a piano and, after careful study, had arrived at the conclusion that the sounds which it produced came from the wires when they were tapped by the hammers. "'Thus far,' says he, 'I have prosecuted my researches,' and he goes on with the blithe optimism of the Atheist: 'so much is evident now, viz., that the sounds proceed not from any external agency, but from the uniform operation of fixed laws. These laws may be explored by intelligent mice, and to their exploration I shall devote my life.' And so the mouse, arguing himself out of the old belief of his kind, becomes convinced that the piano player has no existence."

The philosophical mouse

Paley's traveller on the heath who found the watch and made such intelligent deductions from it, was not confronted amongst the other explanations, which his inventor supposes him to reject, that it existed because it had a resilient spring and was thereby explained. Perhaps Paley did not imagine that anybody would ever seriously advance such an "explanation" as that, yet in the astronomical theory quoted above we have just that explanation and no more.

Paley's watch

However, it is time that we returned from what tends to become a digression, though really

it is very closely connected with our subject, to a further explanation offered by another vigorous opponent of vitalistic views, the very distinguished writer, Professor Weismann. We have already seen how he attempts to deal with the phenomena of regeneration so unaccountable on the mechanical hypothesis. And we have seen that his method of accounting for them, if taken at its face value, amounts to nothing more than a mere restatement of the problem. Professor Weismann is far too eminent a biologist not to see that all vital phenomena require some explanation, and, as he refuses to be persuaded by the vitalistic or neo-vitalistic school, he must perforce offer some other explanation. What is it? Let us try to make it plain.* In the first place he says that "the botanist Reinke" (whose views have already been alluded to in these pages) "has recently called attention once again to the fact that machines cannot be directly made up of primary chemico-physical forces or energies, but that, as Lotze said, forces of a superior order are indispensable, which so dispose the fundamental chemico-physical forces that they must act in the way aimed at by the purpose of the machine." Thus in making a watch; gold, steel, jewels, etc., must not only be brought together, but

Weismann

* *Op. cit.*, i., 402.

brought into a definite relation with one another. Here it is human intelligence which effects the conjunction. "But organisms also are machines which perform a particular and purposeful kind of work, and they are only capable of doing so because the energies which perform the work are forced into definite paths by superior forces; these superior forces are thus the steersmen of the energies." So far we may be all in agreement. That there are superior forces or that there is a superior force is precisely what all vitalists and neo-vitalists contend, and those who believe in a Creator also believe that it was His Will which conferred those powers on living nature. Reinke, from whom quotation has just been made, thinks that these superior forces have been put into the organism by a "cosmic intelligence" which is a polite periphrase, one must suppose, for the Creator.

Weismann will have none of that. Why not? "Because, in the first place, these superior 'forces' are not 'forces' at all." What, then, one asks, are they? The reply is ready. "They are constellations of energy, co-ordinations of matter, and the energies immanent therein, under complex and precisely defined conditions, and it is a matter of indifference whether chance or human intelligence has brought them together."

Here again is a fine high-sounding explanation which on analysis turns out to mean just—nothing. In the very centre of it is embedded a word which begs the whole question and that word is "immanent."

"Inherent"

In this country we generally find that inherent is the term used, but as one means that something is sticking in something else and the other that something is remaining in something else it matters but little which of them we use. Neither of them explains anything, for neither of them tells us the least little bit how the something came to stick or to remain in the other something or what it is which sticks or remains there, and this is precisely what we want to know and what the explanation professed to be about to tell us.

Let us, however, pursue our inquiry into this explanation a little farther. Let us ask whether the phrase "constellations of energy" is only a rhetorical effort or whether it has any real significance in the world of facts. Does its author in any way define it or explain what it means? Yes, we find that these "constellations" are defined as being "the biophors, the determinants, and the 'groups of determinants' which we may think of as disposed in a manifold overlapping series."

We may think, of course, of any subject which

it is not forbidden us to think about, and to think about biophors and the like is certainly not a mortal sin. But have they any real existence? Are we on any solid ground if we look to them as the constituent parts of the constellations of energy in which we are so much interested?

What after all are these biophors and determinants? Most biologists, it is not unfair to say, utterly refuse to believe in their existence and even their describer is obliged to admit that they cannot be seen by the microscope or recognised by any kind of objective test.

They are not objects known to science, for science only deals with observable facts. They are the products of a luxuriant and highly-developed scientific imagination and have been postulated by Professor Weismann for the purpose of explaining the phenomena of nature, and, *inter alia*, of disproving the existence of a vital force in the living organism. In point of fact Professor Weismann builds up an elaborate edifice of imagination, based on no sufficient substratum of fact, and then says, "This is how things may happen" [and of course it is possible that they may] "and as a matter of fact I have no doubt that this is how things do happen and that being so there is no need for your vitalistic theories." To

which it may be replied, first, that there is no kind of evidence for the things by which Professor Weismann explains the phenomena of life, and, secondly, that if they were all as clear and patent as the rails and sleepers on a railway line they would no more explain the operations of nature than those parts of the railway system explain to us how the locomotive comes to be able to haul its load along them.

This explanation then is another example of a verbal explanation which explains nothing. But, as we have already said, it may be argued, the explanation of a vital force—we will retain that name as the most ancient, though it matters little what we call it—this explanation too is a verbal one, since you cannot see that force or detect it by the aid of any instrument.

Is it a verbal explanation?

This we may admit without for a moment consenting to look upon the theory as a mere verbal one, for if we cannot see the force itself, we can see its manifestations, we can compare them with all the other manifestations with which we are familiar, and, by a process of elimination, we can come to the conclusion that here we are dealing with something of a nature different from that of any non-living force and unknown in non-living nature. This is a matter which has been referred to before, but it will not suffer by reiteration, for it is of the essence

of the question that it should be thoroughly understood. We have excellent parallels and precedents for entertaining our belief. No one doubts the reality of gravitation, since all can perceive its operations, yet no one has ever seen this force nor has any person yet propounded an explanation of its nature which has met with anything like general approval in the scientific world.

Gravitation

Or again take the question of the ether, of the existence of which at least the greater number of scientific men seem to have no doubts. Yet Professor Duncan * says that "any discussion of ether leads out upon the high road to incredulity. A thing," he proceeds, "must be defined by its properties and the properties of the ether are for the most part negative; so negative, indeed, are they, that when one says boldly that we cannot see ether, hear it, taste it, smell it, exhaust it, weigh it, or measure it, one feels timid that sane-minded people will meet these negative qualities of our ether by a decided negation of belief in its existence. But the fact of the matter is that if this thing 'ether' is not visible to the eye of sense it is visible to the eye of the mind which is much less liable to err." And he proceeds to show the grounds on which the ether is believed in, purely

The ether

* *The New Knowledge*, 1907, p. 3.

on account of its manifestations and not because it has been made obvious in itself to any of our senses aided or unaided.

If then the vitalistic explanation is verbal only so also is the theory of gravitation and so the existence of the ether.

It shall be left to a distinguished physiologist to have the last word on this subject in the present chapter. Dr Haldane * says: "It is frequently urged that vitalism amounts to nothing more than the mere assertion that a physico-chemical explanation of vital phenomena has not been found; and that even though this assertion be correct, the only possible way to advance in physiology is by the further application of the principles of physics and chemistry, since there are and can be no other kinds of explanation but the causal ones which these sciences afford. This argument in its widest form is undoubtedly based on the metaphysical assumption that the universe, interpreted as it is in the physical sciences as a universe of matter and energy, corresponds to absolute reality, and is for this reason incapable of any further interpretation. The work of modern philosophy since Berkeley and Hume has shown that the assumption in question is without foundation."

* *Loc. supra cit.*

CHAPTER XIII

HEREDITY AND VARIATION

Fertilisation—Parthenogenesis—Heredity—Particulate and Mnemic Theories—Variation.

The ovum from which the adult form develops is in the enormous majority of cases the result of the fusion of elements derived from two parents, male and female. Thus in the vegetable kingdom the pollen granules, shed from the anthers of the stamens of the male plant or portion of the plant, are conveyed by insects or by the wind or otherwise to the stigma of the female plant or portion of the plant. Uniting with the ovules in that portion they form the future seeds. In the animal kingdom the male spermatozoon unites with the ovum from the female, which it enters, fertilises and as a result forms the commencement of a new being.

There are, however, cases in which development takes place without such union. These cases come under the category of what is known as *parthogenesis* and, as some importance has **Parthenogenesis**

been lately attached to them, consideration must now be given to this matter. In certain instances such as that of the Aphides or green-flies which are such a pest on roses, parthenogenesis is the rule for a certain number of generations at any rate, that is new individuals arise *without* the previous union of male and female elements. In other cases such an event it would appear takes place sporadically, indeed it has been suggested that the occurence of the curious teratomata in the ovary of the human female and possibly, though doubtfully, in the testis of the human male, may be attempts at the same kind of thing in the highest living form.

Of late a good deal of attention has been directed to the subject of artificial parthenogenesis by the extremely interesting experiments of Jacques Loeb.* He has succeeded by methods physical and chemical in inducing complete development in certain forms and, most important of all, even in a vertebrate, the frog, without previous impregnation.

These experiments—as to whose remarkable character there can be no difference of opinion—are still in their infancy, and Sir William

Tilden

Tilden—one of the most distinguished of living organic chemists—has stated it as his opinion

* *The Organism as a Whole from a Physico-Chemical Viewpoint.*

that "too much has been made of the curious observations of J. Loeb and others," and goes on to state that when we consider "the propagation of the animal races by the sexual process . . . there can be no fear of contradiction in the statement that in the whole range of physical and chemical phenomena there is no ground for even a suggestion of an explanation." Coming from so weighty an authority these words must be taken as final so far as our present knowledge goes. But the matter must be further considered, and I venture here to repeat what I have written upon it elsewhere, as I have seen no reason to change my opinion since the article in question appeared. Referring to Loeb and his views I have said:

"We find the task of unravelling the writer's meaning rendered more difficult by a certain confusion in his use of terms, since fertilisation, *i.e.*, syngamy—the union of the different sex products—seems to be confused with segmentation, *i.e.*, germination; and this confusion is accentuated by the claim that 'the main effect of the spermatozoon in inducing the development of the egg consists in an alteration in the surface of the latter which is apparently of the nature of a cytolysis of the cortical layer. Anything that causes this alteration without endangering the rest of the egg may induce its

Spermatozoon and ovum

development.' When the spermatozoon enters the ovum it causes some alteration in the surface membrane of the latter which, amongst other things, prevents the entrance of further spermatozoa. Loeb thinks that in causing this alteration it sets up the segmentation of the ovum. That there is a close connection between the two events seems undoubted; that they are in relation of cause and effect seems likely. It is quite evident that an artificial stimulus can in certain cases set up segmentation, but never can it cause the fertilisation of the ovum. It may very likely produce the same change in the membrane that is caused by the entrance of the spermatozoon under normal circumstances—membrane formation may be necessarily coincident with the liberation in the egg of some zymose which arises form a pre-existent zymogen. But we are still some way off any assurance that the *main* object of the spermatozoon in inducing the development of the egg is this surface alteration. It may be the initial effect; very probably it is; but since the main function of the spermatozoon must be the introduction of germplasm from the male parent, it is too much for anyone to ask us to believe that its main function is concerned with surface alteration."

Here we may break off from the quotation

for a moment to consider how frequently the characteristics of the male parent appear in the offspring. When I was thinking over this chapter yesterday I happened to see a mongrel with whose parentage I was fully acquainted, since she was the offspring of a pure-bred black cocker spaniel of my own and—I regret to say—an Irish terrier. The result is a red-haired dog not very like either of her parents, but in no way resembling her spaniel mother. This and thousands of other cases prove—if proof were needed—that the *main purpose* of the spermatozoon is to introduce elements from the other or male parent. The other effect is very possibly there; but it is hardly the main effect. To return to the quotation:—

"Loeb argues that the change in the surface membrane is of a chemical character, and that no doubt may be correct; but even if we allow him every scientific fact, or surmise, he is still, as in the other cases with which we have dealt, miles away from any real explanation. He is still inside his chemico-physical explanation to begin with; and, even within that, he still leaves us anxious for the explanation of a number of points—for example, as to the nature of the chemical process which accompanies, or is the cause of, segmentation. We in no way press these questions; for similar

demands could be made in so many cases; we only indicate that they are there. What we do press is this—that when an authority comes forward to assure us that all the processes of life, including man's highest as well as his lowest attributes, can be explained on chemico-physical lines, we are entitled to ask for a more cogent proof of it than the demonstration, however complete, of the germination of an egg, caused by artificial stimulus and not by the ordinary method of syngamy, even though that germination may lead to the production of a perfect adult form. We are entitled to ask him to make clear to us not only what is happening *within his system*, but—which is far more important—what that system is, and how it came into existence. We are entitled to ask why the artificial stimulus, or the entry of the spermatozoon, produces the effects which it is claimed to produce instead of any one of some score of other effects which it might conceivably have produced. Above all we are entitled to ask why there are any effects, or even why there is any ovum or any spermatozoon or curious physiological investigator, to give the artificial stimulus. Until some light is thrown upon these things we are still within the system, or merely hovering round its confines, and are far away from any final or philo-

Unanswered questions

sophical explanation such as would satisfy the mind of the man who wants to get a real and not a partial knowledge of the things around him." *

The instance of heredity alluded to a few lines above may act as an introduction to the consideration of this much-debated subject. It is matter of common knowledge that whilst on the whole offspring do resemble their parents yet they are never identical with them. That is :— there is such a thing as Heredity and there is also such a thing as Variation. Both of these topics will repay consideration. Heredity exists, and since the re-discovery of the writings of Abbot Mendel of Brunn and the vast amount of work consequent upon that re-discovery, we seem to be acquiring some knowledge of some of the laws under which it works. But of the *Mechanism* of it we are still ignorant. We know that the offspring of a cat will be kittens not puppies—a wonderful enough thing if we were not hardened to it by constant repetition— that is we know that one kind of thing breeds that kind and not another.

Heredity and variation

We know from Mendel and his followers that we must examine the separate characters, rather than the *tout ensemble* when we are examining into the laws of heredity. We may be

* *Science and Morals.* Burns & Oates, 1919.

tolerably certain, in spite of Brown-Sequard's epileptic guinea-pigs which have not carried universal conviction, that mutilations are not inherited; indeed the age-long experiments in circumcision in more than one race and the docking of puppies' tails seem to prove this. Are we equally assured that no acquired characteristics are inherited? Some would have us believe so, and amongst them Weismann in at least his earlier writings. Yet, if this be so, how are we to account for such cases as that of the Porto Santo rabbits? For a full account of these the reader may be referred to the pages of the book from which I have been quoting above. Here it need only be said that it is historically clear that these rabbits are the descendants of some breed of the ordinary and well-known rabbit introduced on an island where they had neither carnivorous animals nor birds to disturb their breeding some centuries ago. Since that time they have developed into creatures which would be described as belonging to a totally different species were it not that their history is so well-known; and—most significant fact of all—into creatures which will not breed with the ordinary rabbits of Europe from which they are quite undoubtedly descended. All these things we have learnt about heredity, but we

Porto Santo rabbits

have at present no real idea of how the hereditary characteristics are transmitted. There have been various attempts to solve this riddle to which some attention must now be paid. In the first place there is what is known as the *Particulate* group of theories to which the Darwinian *Pangenesis* belongs. According to this and other similar theories small germs—Darwin's *pangenes*, also called by other names by other theorists such as Galton, but all meaning the same thing—are shed from each part of the body, collected in the ovum or spermatozoon and grow in the developing individual, producing, so to speak, the plants from which they were shed.

Particulate theories

It is the most obvious theory and in one way or another it may be said that it is the theory which commands the greatest amount of support to-day. There are two points, however, to be considered in connection with it. In the first place the theory requires it to be assumed that amongst the germs contained in the sex-product there shall be not only representatives of even the smallest parts of the parental bodies —since the very smallest peculiarities may be transmitted and even for generations—but also of all the ancestors of those parents since atavism or "throws-back" have to be taken into consideration . Hence it has been urged by some

that the composition of the sex-products would, in these circumstances, be too complicated to be thinkable. However this may be, and according to prevalent physical ideas as to the composition of matter there is room for an enormous number of particles in the spermatozoon, not to speak of the ovum, there is a further matter and that is the question of arrangement—a word often used with great freedom but, one is bound to say, less consideration as to its exact meaning. For example, in a recent British Association Address, the President committed himself to the opinion on the matter we are now considering that "though it is obvious that they are transmitted by the sex-products it is unlikely that they are in any simple or literal sense material particles." Here we may break off for a moment to inquire, in the interests of plain thinking, how we are to understand this passage. A thing must be either material or immaterial simply and literally and it cannot be both. But to proceed, for what follows is much more important. "I suspect rather that their properties depend on some phenomenon of arrangement."

Bateson

Let us deal fully with this question of "arrangement," and to make it clear let us consider the following parable. Let us suppose that a visitor to some well-arranged garden is

anxious to have just such another for himself. He has a piece of land of similar size; the owner of the garden is willing to let him have seeds or cuttings representing everything that he has; the ground is dug and prepared; what else is wanting? Obviously a plan of the first garden indicating where each particular seed or cutting should be placed, without which there could be no true copy, for where there were columbines in one garden there might be lupins in the other and so on. In one word there must be arrangement—intelligent arrangement. Suppose there were one hundred different plants in the original garden and the seeds were sown haphazard in that which is intended to be a copy: what are the odds against the two being exactly similar? Any mathematician will tell you; but they will be fairly long odds. Let us allow for a moment—in spite of the difficulties attaching to such a theory—that there are in the sex-products germs of each part of the adult body; they are useless without arrangement. What is there to place the blue eyes of the mother and the Roman nose of the father in the middle of the face of the offspring instead of their being scattered about in odd parts of the body? Hence the particulate theory, if it be true in any respect, is impossible without the aid of the vital factor, for the entelechy or

"Arrangement"

"form" is the arranger. When we see in books as we sometimes do that such and such a thing is a "phenomenon of arrangement," a favourite expression, let us not go away contented but reflect that when we sit down to a well-appointed and prettily decorated dining-table we do not indulge in platitudes about "phenomena of arrangement," but congratulate our hostess on her taste and on the skill of her butler or her parlour-maid.

The mnemic theory

Another theory to account for inheritance is that known as *Mnemic* and advanced by Hering and with much greater force by Samuel Butler. This teaches that it is the recollection of the embryo which causes it to go through the stages which its progenitors had previously traversed. The memory is of course unconscious, like much of our adult memory perhaps. The same idea is the basis of Rignano's *Centro-epigenetic hypothesis*. We need not delay over the criticism of these theories, full of interest though they are, since, for our present purposes they possess one altogether fatal flaw:—no one can possibly remember a thing which neither he nor anyone else has ever done before. *Ex hypothesi* the single cell divides and becomes first a congeries of cells; then an adult form and all because it is acting upon the unconscious memory of what its an-

cestors have done. But again *ex hypothesi* its original ancestor was unicellular all its life. How did the first multicellular form arise? Certainly not by memory.

Last of all there is the chemical theory of inheritance which seems as if it was going to be the popular theory of the immediate future. It is not necessary to deal with this at any great length for, in the first place, the argument which has just been used as to arrangement will and must apply here also, and secondly because the extreme rigidity of chemical and physical processes here affords a proof that though they go on of course in living things, they cannot be the dominant factors. The ordinary reader can scarcely have any idea of the extreme rigidity and regularity of physico-chemical phenomena. Let us take one example.

Chemical rigidity

The composition of stars distant billions of miles from this earth and from one another is ascertainable by spectroscopic examination. The variation in the spectra of different substances is due to the variation in the number of vibrations per second of the electrically charged systems of atoms. The number of these vibrations is enormous, from 670 billions per second at the violet end to 460 billions at the red. Yet the vibrations are all perfectly in time, for there is no blurring of the spectrum.

In fact, Schuster calculated that the separate vibrations amongst the atoms of an element do not differ from one another *so much* as would be represented, in a collection of clocks, by one out of every eight losing or gaining one second in every twenty-three days. Rigidity of this kind is not recognisable in the realm of life, where an additional factor appears in the shape of that tricksy sprite Variation, the cause of which has so far eluded all observers. Yet its operations we see around us every day of our lives, and they are the basis of the transformist hypothesis.

There are small variations which seem to oscillate round a centre, the small variations on the accumulation of which Darwin counted but which to-day have lost with most biologists the distinction which they once possessed as the foundation of new species. There are large variations, sudden in character and now known as Mutations, as to which there can be scarcely any doubt in the vegetable world, even though doubts have been thrown on the character of de Vries' classical observations on the Evening Primrose. The fact is that we know too little about this last factor to attempt to bring it into any final synthesis with any feeling of security.

If philosophy is the *Scientia Scientiarum*, she must look to the other sciences for her facts, and

until she has those facts it would be mere foolishness to attempt to arrive at conclusions.

All, therefore, that we can safely say here is that, in spite of the views which have been tentatively put forward as to a process of evolution which may be taking place in the inorganic world, and which might, if true, point to some form of variation being found there, observation plainly shows us that rigidity of operation is the main characteristic of that kingdom; variation of the other. And, from what we have observed on other points, we shall certainly not be surprised if the cause of variation is of a purely vitalistic character.

CHAPTER XIV

THE LAW OF THE CONSERVATION OF ENERGY

"Laws" of Nature—Energies of Life—Matter and Form.

It will be remembered that Driesch in his historical sketch alluded to two scientific discoveries and theories which had had a powerful effect in discountenancing vitalism, at least for a time.

Law of conservation of energy

The first, and by far the more important of these, is the difficulty presented or supposed to be presented by the Law of the Conservation of Energy.

Physical energy, that is to say the capacity for doing work, may be of two kinds. It may be kinetic or in actual evidence, as it is in a flying bullet or a moving railway-train, or it may be potential or not evident to the careless eye as it is in a suspended weight. Now many experiments have been made respecting these different kinds of energy and respecting the different varieties of energy of which we shall have to speak shortly, and as a result of these experiments the following facts emerge or appear to emerge.

First of all it seems perfectly clear that when one form of energy is changed into another, nothing is lost nor is anything gained. Consequently the following so-called " laws " have been formulated by men of science :—

1. That the sum of the kinetic and potential energies of any isolated system of bodies remains constant; and—

2. That the sum-total of the energy in the universe remains the same.

Before considering the bearing of these laws on the question under consideration it will be well to be quite clear in our minds as to what is meant by a law of nature and what its precise value is.

The word "Law " has two distinct meanings, not unfrequently confounded. Sometimes the term stands for a decree or command, expressed by a sentence in the imperative mood. The Ten Commandments and Acts of Parliament are " laws " in this sense. At other tmes the term denotes some observed uniform mode of action or behaviour in phenomena which is signified by a general proposition in the indicative mood. The laws of chemistry and astronomy are examples. Now it cannot be too clearly kept in mind that the " laws of Nature " are of this latter kind.

Laws of nature

The term simply expresses our appreciation or

conception of an orderly or supposed orderly sequence of events in the natural world. Viewed strictly from the standpoint of science, as Huxley was careful to point out, there are no such things as laws in the ordinary sense of precepts or decrees, in the processes of Nature. What we do know is that there are certain observed sequences of events and that these do actually present to us a picture of a uniform nature. But this is a different thing from assuming, as many without any evidence are prone to do, that these sequences are the result of some inexorable compulsion or some intrinsic and absolute necessity emerging out of the nature of the universe, and that in no other way could things take place than that in which as a matter of fact we are accustomed to find that they do take place.

As it is of the first importance that those who are not accustomed to dealing with scientific theories should understand the real value of these so-called "Laws," I will add one further quotation on the subject from one of the acutest thinkers and most accomplished physicists I

Poynting have ever known.* "We must confess that physical laws have greatly fallen off in dignity. No long time ago they were quite commonly described as the Fixed Laws of Nature, and were

* The late Professor J. H. Poynting, F.R.S., in a British Association Address, 1889.

supposed sufficient in themselves to govern the universe. Now we can only assign to them the humble rank of mere descriptions, often erroneous, of similarities which we believe we have observed." And again:—"A law of nature explains nothing—it has no governing power, it is but a descriptive formula which the careless have sometimes personified. There may be psychological and social generalizations which really tell us *why* this or that occurs, but chemical and physical generalizations are wholly concerned with the *how*."

"For those who accept the theistic position," as Fr. Sharpe very clearly puts it,† the *rationale* **Sharpe**
of the whole matter is this. The observed course of Nature is due to the action of divine power, which having certain ends in view attains them in the most suitable way. So long, therefore, as the ends in view remain the same, the means adopted for their attainment will not vary; and a slight or infinitesimal variation in the ends will bring about a precisely corresponding variation in the means. But the ends to be secured by the course of Nature are always the same; or if they vary, do so by an infinitesimal gradation. The sensible world consequently presents, so far as the general experience of mankind goes, the appearance of strict regulation.

† *Op. cit.*, p. 133.

Furthermore it is to be remembered that our conception of these uniformities or laws of Nature are based on our present experience, and that the extension of that experience may require us to introduce modifications into our expression of the facts as they appear to us, or, in other words, may lead to a change in the formulation of the law. In fine there is nothing sacrosanct about the laws of Nature, which forbids criticism or denies the possibility of error in our comprehension of them.

Vital energy

With these prefatory remarks we may attack the problem before us and at once admit that much difficulty has been felt in accounting for the power which, we have endeavoured to show, exists in living matter, the power which directs and, still more, initiates chemico-physical processes in the living organism. Is it subject to the laws above detailed? Where does it come from, and whither does it go? Many attempts have been made to clear up this difficulty though some maintain that it is no difficulty at all. Professor B. Moore, for example, as we have seen, believes in what he calls a "biotic energy," and this energy is, he thinks,* "just as closely, and no more related to the various forms of energy existing apart from life, as these are to one another, and that in the presence of the

* *Op. cit.*, p. 4.

proper and adapted energy transformer, *viz.*, the living cell, it is capable of being formed from or converted into various of these other forms of energy, the law of conservation of energy being obeyed in the process just as it would be if an exchange were taking place between any two or more of the latter forms." It would hardly seem that Professor Moore had escaped from all the difficulties of the situation by this method of leaping over the fence, for we still require an account of the action of "the proper and adapted energy transformer, *viz.*, the living cell" this being exactly the difficulty that is encountered in all the solutions of the difficulty which have been heretofore proposed.

The spark and the explosion

It has, for example, been urged that the power which frees the energy is so small that it may be regarded as inappreciable when incorporated in the total result. In fact it has been compared with the tiny spark which is capable of exploding a mine of blasting-powder and releasing an enormous amount of energy by the expenditure of an amount which is so small as to be almost negligible in the whole account of the transation.* To some extent, no doubt, this is all

* "So comparable with this is the discharge of a projectile by the minute work of a trigger, or it may be the still minuter work of an electric spark liberating foot-tons of energy in a cannon, that organic response is termed *action á détente* (trigger action) by the French, and *Auslösung* (letting-off) by the Germans: we might term it '*release!*'" Hartog: *Problems of Life and Reproduction*, p. 229.

quite true. "As far as we can judge," says Balfour Stewart, "life is always associated with machinery of a certain kind, in virtue of which an extremely delicate directive touch is magnified ultimately into a very considerable transmutation of energy." That we may look upon as an assured fact, but we have still to consider whether the "directive touch" is a form of energy. In this connection we cannot neglect

Catalysts

the important subject of catalysis, the name given to chemical actions brought about by a substance which is called the "catalyst," which substance is, after the action is over, recovered unaltered. For a complete account of this matter, works on chemistry must be consulted, but as a concrete example it may be mentioned that platinum either in sheet or in spongy form will cause or hasten action without itself undergoing any kind of change detectable by the chemist. And so with other bodies from which it appears that action *may* be caused or directed by a body which itself undergoes no change. In the living body something very similar seems to take place with regard to the products of the endocrine glands such as the thyroid, thymus, adrenal and others.

Hormones

These products are known as hormones, and their discovery has cleared up the difficulties which have for long been felt as to the use—

if any—of some of these organs. A few examples will explain what is meant. There is a tiny body called the Hypophysis or Pituitary body which hangs like a small currant from the base of the brain and lies in a hollow in the skull known as the Sella Turcica. Up to a very recent time it was supposed to be without any special use or function, yet it is now known that it is of the most profound importance, since its functions are associated with the growth in stature of the possessor. Giants, for example—a feeble folk in actual life whatever they may be in folk-lore—owe their unhappy condition to an excess in size and function of this gland; the so-called acromegaly. Incidentally it may be remarked that the discovery of these internal secretions has knocked on the head a great deal of the foolish talk in which many of us used to indulge with regard to "Vestigial Organs"; these organs having turned out to be anything but vestigial, in fact, fraught—as in the case of the thyroid—with issues of life and death to the individual. And with this discovery there must be jettisoned an infinite amount of phylogenetic theory as well.

Let us take another case: there are two little organs shaped something like cocked hats which sit on the upper margin of either kidney in the human being. These are called the adrenals or

suprarenals, and up to a very recent time the only fact that one knew about them, beyond the anatomical information that they were rather unusually richly supplied with blood vessels and nerves, was that they were at times subject to a rare form of disease in which the sick person turned a more or less rich chocolate colour, a disease known, from its first describer, as *Morbus Addisonii.* Now it is known that these little bodies produce a most potent internal secretion known as adrenalin, which amongst other things is highly styptic and also seems to be poured out with great freedom when the owner of the glands is indulging in a fit of temper. This is certain, that the amount of these secretions is infinitesimal in relation to the far-reaching effects which they produce; they are stimuli, —veritable sparks applied to piles of explosives. Do these organic catalysts, for thus we may fairly describe them, follow the rule of those of an inorganic nature and undergo no change themselves? It is perhaps too early in the history of these very recently discovered bodies to pronounce any very definite opinion on this point. They are infinitesimal in relation to the effects they produce; that, as we have said, is clear. In certain cases they seem to undergo oxidation and to be eliminated after producing their effect, in which case their action

Adrenalin

would be mainly if not entirely directive, and they would be merely got rid of by means of an ordinary method of chemical change when done with. Again, the vitamines, now known to be of such immense importance, are known also to be infinitesimal in connection with the effects which they produce. It is the absence of the appropriate vitamines—for example, the vitamine which exists immediately under the skin of a potato, which causes scurvy which was such a scourge to sailors until it was discovered empirically and long before vitamines were ever heard of, that fresh vegetables or lime juice would prevent its advent. **Vitamines**

Another vitamine, removed from rice by what is known as "polishing," by its absence causes beri-beri, a disease of the nerves in those whose chief diet it is. This disease can be experimentally produced in chickens by feeding them with polished rice, *i.e.*, rice from which the outer surface has been removed, and the disease can be cured, and rapidly, by giving them doses of the removed outer coat which contains the vitamine. Finally, there are the "anti-bodies," **Anti-bodies** produced in the organism by vaccines, autogenous or otherwise, as to which our knowledge is as yet only in its infancy. In all these cases the action seems to be more or less directive, though it would be more than rash to dogmatise

about them. They certainly seem to exemplify those ideas of control and release of which more will be said in succeeding pages. Even if it turns out on further investigation that these facts do not solve the question, they seem to throw considerable light upon it, and in any case it would be rating the content far too high were we to conclude that the Law of the Conservation of Energy excludes the possibility of the existence of a power controlling the operations of the cell? To infer this fact would be to assume, as we have no right to do, that we know all about the Laws of Nature and the particular Law in question, as well as to assume that the facts of living matter are opposed to the law as at present formulated, which is by no means certain.

"The very advance of physics," says Ward,* "is proving the most effectual cure for this ignorant faith in matter and motion as the inmost substances rather than the most abstract symbols of the sum of existence."

Are we then to argue, as some have done, that the Law in question, whilst applicable to all inanimate Nature is abrogated in the world of Life?

Here it is prudent to revert to the considera-

* *On the Conservation of Energy*, p. 163.
* *Op. cit.*, 180.

tions urged at the commencement of the chapter as to the real nature and significance of the term " Law of Nature," and to remember that this really means a generalisation from the facts before us up to date. " The term 'energy' itself," says Sir Oliver Lodge,* " as used in a definite sense by the physicist, rather involves a modern idea, and is itself a generalisation. Things as distinct from each other as light, heat, sound, rotation, vibration, elastic strain, gravitative separation, electric currents, and chemical affinity, have all to be generalised under the same heading (of the Conservation of Energy) in order to make the law true. Until 'heat' was included in the list of energies, the statement could not be made; and a short time ago it was sometimes discussed whether 'life' should or should not be included in the category of energy. I should give the answer decidedly No, but some might be inclined to say Yes; and this is sufficient as an example to show that the categories of energy are not necessarily exhausted; that new forms may be discovered; and that if new forms exist, until they are discovered, the Law of Conservation of Energy, as now stated, may in some cases be strictly untrue, though partially and usefully true; just as it would be untrue,

Energy

* *Life and Matter*, p. 21.

though partially and usefully true, in the theory of machines, if heat were unknown or ignored."

We may feel perfectly clear from what we know best ourselves from our intimate and everyday experience, namely, conscious human life, and from the processes which take place in living matter, that life or the vital principle does modify the forces, energies, and movements of matter. Is it not perfectly obvious that the war-fever, religious revivals, electoral excitements are all ideas, yet all exercise potent influences over the energies and movements of matter, in the shape of human beings, not to speak of all the material activities which they control?

If the arguments in favour of the existence of an energy in living matter which is not to be found amongst the known energies of chemistry or physics are conclusive, as they appear to be to the present writer, and, as he has tried to show, to many men of science whose claims to be heard on this point are far greater than any which he can put forward, then it is quite clear either that the Law of Conservation of Energy is incorrectly formulated and will require modification when the state of our knowledge is more advanced, or that the form of energy in question stands to the Law in some

relation which has not yet been made quite clear.

Before leaving the matter there are certain points which must not be left out of consideration. Let us commence by considering the question of "direction," which we have already raised.

Directive power

We recognise, of course, that there is a certain amount of energy displayed in all material activity. But this is not all. There is also a directive power, and this power plays the part of an orienter, so to speak, of the energy, though it does not increase or diminish its sum. We have, therefore, to recognise a qualitative element in all such operations. In fact, mechanism itself remains absolutely inexplicable if we try to reduce everything to the play of mechanical forces.

Hence we are driven, at all costs, to recognise a duality, the very duality so much objected to by the monistic school.

It is quite clear that an agent may modify the direction of a force or a moving particle without altering the quantity of its energy or adding to the work done. That is to say, it is possible to bring forward an example of a purely qualitative influence.

For a power acting at right angles to the motion of a body can alter the direction of that

body without increasing or diminishing the intensity of the motion.

The earth revolves around the sun in its elliptic course because the force of gravity holds it in that course. Suppose the sun were suddenly to disappear. Its attraction at an end, the earth would rush away at a tangent. The energy which it displays would not be altered in any way, but the direction would be wholly changed.

The will

Of course it may be asked whether one can in any way show that the Will or the Vital Power does act at right angles to the forces of any material energy of the organism. That, however, is an objection or an inquiry which we may rightly consider to be unfair.

All that one can be asked to do is to show that there is a method by which an agent *can* modify the action of physical energies without altering their quantity.

So far, however, we have only spoken of the modification of a force "in being"; how about the initiation of the force or the initiation of the change of energetic direction? The pressure of the button which completes an electric circuit may produce prodigious effects, altogether out of proportion to the power exerted in the preliminary pressure; but pressure there must be.

In this connection we must remember Kant's dictum * that "if we seek the cause of any change of matter whatever, in life, we shall have to seek it at once in another substance, distinct from matter, although bound up with it."

"It is in meeting this difficulty," says Fr. Maher, † "that the Scholastic conception of the relation of Soul and Body in the theory of Matter and Form is most helpful. In that theory the vital principle is the 'form' or determining principle of the living being. Coalescing with the material or passive factor, it constitutes the living being. It gives it its specific nature, it unifies the material elements into one individual. It makes them, it constitutes them, it holds them a living being of a certain kind. Biology teaches us that the living organism is a mass of chemical compounds, many in very complex and unstable equilibrium. They are, many of them, tending of themselves to dissolution into simpler and more stable substances, and when life ceases the process of disintegration sets in with great rapidity. The function, then, of this active informing principle is of a unifying, conserving, restraining char-

Matter and form

* *Metaphysische Anfangsgrunde der Naturwissenschaft*, ed. Hartenstein, vol. iv., s. 440.

† *Life and the Conservation of Energy in the Lower Animals.* My lamented friend, the author of this paper, lent it to me in MS. I fear that it was never published.

acter, holding back and sustaining the potential energies of the organism in their unstable conditions. In this view of the relation of the vital principle to the material elements of the organism, it is obvious that the transformation of the potential energy of the organism may be effected without any form of positive pressure, however small.

"It will suffice simply to 'let go,' to cease to hold back and the energies thereby liberated will tend of themselves to issue from their unstable conditions.

"Conceive a sack of potatoes or a bladder of gas or water. Suppose that sack or bladder endowed with the power of giving way in particular places. The contents will at once issue forth into outer space by the force of gravitation or of their own mutual repulsions.

"Somewhat in a similar way the 'Soul,' 'Vital Principle,' or 'Form' is holding and preserving the material elements of the organism, not in a particular space, but in certain states and conditions of unstable equilibrium."

In conclusion, as regards this matter, it may candidly be admitted that the last word on the problem of the Conservation of Energy in its relation to Life has not yet been said. But, at the same time, it is also clear that the supposed rigidity of the Law in question is in itself no

reason why we should be called upon to deny a fact which seems to be otherwise clearly demonstrable, and, it is also clear, that whether we are yet on the right track or not, it is at least possible to make some suggestions as to the direction in which the final solution of the difficulty may some day be arrived at.

The common-sense way of looking at the matter is something like this. No one but an ignoramus will claim that we know all that can be known about the so-called Law of the Conservation of Energy. If it is clear—as it seems clear to many persons—that there is something more in living bodies than the mere operations of chemistry and physics, then the "Law" will require adjustment to that fact. Why not? There is nothing blasphemous in the suggestion, though one might think so from the reverence which is paid to the Law as now formulated.

What is more; this adjustment has had to take place on more than one occasion, notably in connection with the discovery of radium and its ways—for which adjustment see the books on matter and energy.

If there is such a thing as an entelechy, and if it seems to be incompatible with the Law of the Conservation of Energy, then it clearly follows that we do not know all that there is

to be known about that Law and must set ourselves to make a further study of it.

Darwinism

The other obstacle to the acceptance of the vitalistic theory was the sudden rise of what is called Darwinism and the altogether mistaken opinion then held of the bearings of this doctrine on the question with which we are concerned. It will suffice to say that the estimation in which Natural Selection—the central theory—is now held, is not by any means that which it was in the latter part of the last century. Further, it is very hard to see what bearing, if any, that theory has—even if accepted in all its fulness—on the question of Vitalism, for Natural Selection can only act upon the living thing when it is in existence; it cannot produce it.

CHAPTER XV

THE "SOMETHING OVER"

Neo-Vitalists and their Definitions—Conclusion.

PROFESOR WARD * very forcibly describes the characteristics of living matter when he speaks of its "tendency to disturb existing equilibria, to reverse the dissipative processes which prevail throughout the inanimate world, to store and build up where they are ever scattering and pulling down, the tendency to conserve individual existence against antagonistic forces, to grow and to progress, not inertly taking the easier way but seemingly striving for the best, retaining every vantage secured, and working for new ones."

In the preceding chapters an attempt has been made to show that these and the other remarkable characters of living matter cannot be adequately explained in terms of chemistry and physics, and that the view here upheld is that of a large, an important, and, it may be added, an increasing number of those who have made a life-study of different branches of biology.

* *Op. cit. supra*, i. 285.

But if the facts in question cannot thus be explained we are then driven to the conclusion that there is a "something over" in living matter which does not exist in non-living.

"Something over"

Some call this a "vital force," others, apparently thinking that that term savours of mediævalism and supersitition, prefer to invent some new name.

It does not seem of any very great consequence what we call this force, and a careful study of the different definitions thereof leads one to the conclusion that the thing concerning which all the neo-vitalists are dealing in their works is the same, though the names which are applied to it may be quite different.

Neo-vitalism and vitalism

Moreover, if there is any meaning to be got out of words, the thing which the neo-vitalists mean is precisely the same thing as the vitalists—or, at least, those of the scholastic wing—also meant and mean. There was—perhaps may be still—a school of vitalists who looked upon the vital principle or the human soul as a little demi-god living in the body, as Descartes supposed in the pineal body, but not of it, though directing its actions and presiding over all its functions. Vitalists of this kind would also conceive of the animal soul or vital principle, or whatever term they might use for it, as being a thing apart from the body of the

animal—or the vegetable as the case may be. But that is not the view of scholastic philosophy. That its attitude has been misunderstood is probably due to the fact that those who have criticised it have often refrained from what they no doubt considered the unnecessary labour of trying to understand its terminology, which is its own and is not to be at once grasped by the casual outsider. Those who are aware of this fact will smile at Professor Huxley's statement that he plucked the heart out of the works of Suarez during a summer afternoon's study in the library of a Scotch University. If I say to the man whom I may casually meet in any smoking-room, "$H_3C_6H_5O_7 + 3NaHCO_3 = Na_3C6H_5O_7 + 3H_2O = 3CO_2$," he willl probably tell me that he has forgotten all the algebra which he learnt as a boy and that my remark is unintelligible to him. Whereas, if I say, "If you add lemon juice to baking-soda the mixture will fizz," his reply will probably be that my information is accurate if antiquated. Yet the two statements are precisely the same or connote exactly the same occurrences only that one is in the language of the chemist, the other that of the kitchen.

Huxley and Suarez

In the same way if we define the animal soul as a simple, incomplete substance or substantial principle immersed in matter, that definition is

drawn up with the purpose of making clear the fact that in matter and life we have not two complete beings accidentally conjoined, but two constituent factors or principles making up or coalescing into one complete being of a definite nature. Hence the scholastic would define the vital principle as an intrinsic principle of the living cell constituting it living and differentiating it from non-living matter.

It is hard to see how this definition and this way of looking at living matter differs from Professor Moore's definition of what he calls biotic energy, namely, "that form of energy peculiar to living matter, and exhibited in those energy phenomena which are confined to living matter and are indeed its intrinsic property, by which it is differentiated and known to be alive."

The present writer confesses that to him at least the two definitions appear to be absolutely identical in essence and he thinks that the same might be said of Claude Bernard's statement: *

Claude Bernard

"Arrivês au terme de nos études, nous voyons qu'elles nous imposent une conclusion très générale, fruit de l'expérience, c'est, à savoir, qu'entre les deux écoles qui font des phénomènes vitaux quelque chose absolument distincte des phénomènes physico-chimiques ou

* *Vide* Hertwig, *op. cit.*, s. 131.

quelque chose de tout à fait identique à eux, il y a place pour une troisième doctrine, celle du vitalisme physique, qui tient compte de ce qu'il y a de spécial dans les manifestations de la vie et de ce qu'il y a de conforme à l'action des forces générales: l'élément ultime du phénomène est physique; l'arrangement est vital." This view which distinguishes itself from the physico-chemical theories and, whilst allotting only those processes which are the outcome of general physical forces to the material element, assigns to "l'arrangement" or organising property (or "energy" or "force") the special vital phenomena, seems to approximate very closely to the old scholastic conception of the "forma substantialis" or the vital energy of the living body.

Let us contemplate ourselves

But enough of definitions. If we clear our minds of such things and contemplate ourselves, is it really possible to conceive that what we know best amongst the activities of life, our own conscious states, our thoughts, our feelings and our volitions are nothing but physical "energies" or "forces" and are explicable in the same terms as the making of soda water is explicable? Is it not clear that the two classes of phenomena are wholly different from one another and that the activities of life are agencies of quite a different character? As Father

Maher puts it * "they are phenomena unextended and indivisible, quite beyond the ken of physical science; and they are never convertible into any of the forms of 'energy' with which physical science deals. As Tyndall admitted, 'the chasm between them is intellectually impassable.'"

"Correlated with mind," says Professor Ward,† "the complex characteristics of all forms of life are intelligible; but to interpret them literally in terms of physical interaction, and apart from mind, is surely impossible."

In conclusion the writer might perhaps be allowed to say that his first object was to bring forward such biological evidence as had come under his notice in favour of a vitalistic or a neo-vitalistic—for as has been shown, the two are identical—explanation of living matter. Incidentally only has it been possible to touch on the question of the human soul and its relation to the activities of the human body, which is a matter for theologians rather than for biologists to deal with. Nor has he desired to occupy himself with many fascinating, if difficult, philosophical problems such as that formulated by Scotus as to the relations of the operations of the cells or collections of cells into

Scotus

* *Life and the Conservation of Energy.*
† *Op. cit.*, i., 285.

organs with the body of which they form a part. Whether all the "energiæ" are parts of a whole, or whether, as Scotus taught long ago, there are inferior or subservient kinds of "forms" or "energiæ" within the organism dominated by and participating in the supreme "energia" which unifies and animates the whole organism, is not of any great consequence to the main thesis with which this book has endeavoured to deal, however interesting a subject of discussion it may be in itself.

INDEX